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ABSTRACT

This parts failures identification manual is one of a series of power mechanics texts and visual aids covering theory of operation, diagnosis of trouble problems, and repair of automotive and off-the-road construction and agricultural equipment. Materials provide basic information with many illustrations for use by vocational students and teachers as well as shop servicemen and laymen. Each of the eleven chapters shows pictures of failed parts followed by a brief explanation and reasons why the part might have failed. Chapters are (1) Pistons, Rings, and Cylinder Liners; (2) Journal Bearings: (3) Valve Gear Trains: (4) Turbochargers; (5) Gears: (6) Shafts, Axles, Spindles, and Universal Joints; (7) Hydrostatic Transmissions: (8) Anti-Friction Bearings; (9) Belts and Chains: (10) Tracks and Tires: and (11) Miscellaneous Failures. A glossary is appended. (A supplementary 35mm color slide set is also available--see availability note.) (LRA)

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ED185332

Identification of Parts Failures

JOHN DEERE

FOS

FUNDAMENTALS OF SERVICE

CE 024 797

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TO THE READER

This manual shows many pictures of failed parts. A brief explanation follows each picture and gives reasons why the part might have failed. These causes are not necessarily the only conditions that could cause the part to fail. All factors concerning the operation and maintenance of a machine must be considered when analyzing failures.

In most cases the failures shown are secondary failures — some other problem may have caused the failure of the part that is pictured. For example, a piston ring may be scratched or scored because dirt particles became trapped between the ring and cylinder liner. The dirt particles could have entered the engine through a hole in the air cleaner element. The element must be replaced, along with the piston rings, or the same thing will happen and the new rings will fail.

It is important to find the original problem area (the air cleaner element in the above example) when diagnosing failures of any part.

This manual cannot identify all causes of failed parts. Where the cause of failure cannot be determined in the field, the part may require examination by a qualified materials engineer. Information on service and operation should be provided with the failed part.

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Lipson & Colwell, Handbook of Mechanical Wear, 1961, University of Michigan Press, Ann Arbor, MI.— pg. 5-4, Figs. 14, 16; pg. 5-5, Fig. 18

Machine Design Magazine, October 13, 1966, article by Henry Suss, General Electric Co., Schenectady, NY.—pg. 11-2, Figs. 8, 9

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Donald J. Wulpi, How Components Fail, 1966, American Society for Metals, Metals Park, OH.—pg. 5-2, Fig. 3; pg. 5-4, Figs. 13, 15; pg. 5-8, Figs. 34, 35 pg. 6-4, Figs. 13, 15; pg. 11-2, Figs. 5-7

WHAT IS "FUNDAMENTALS OF SERVICE"

This manual is one of a series of texts and visuals called "Fundamentals of Service," or "FOS." These materials are basic information on power mechanics for use by teachers as well as shop servicemen and laymen. All types of modern equipment are covered — both automotive and off-the-road (construction and agricultural types). Emphasis is on theory of operation, diagnosis of trouble problems, and repair.

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CONTENTS

Chapter 1 — PISTONS, RINGS, AND CYLINDER LINERS

Introduction 1-1
Identifying Piston Failures in Gasoline Engines 1-1
Identifying Piston Failures in Diesel Engines 1-3
Identifying Piston Ring Failures 1-6
Identifying Cylinder Liner Failures 1-10

Chapter 2 — JOURNAL BEARINGS

Dirt 2-1
Lack of Lubrication 2-2
Improper Assembly 2-2
Misalignment 2-3
Overloading 2-3
Corrosion 2-4
Electric Current 2-4

Chapter 3 — VALVE GEAR TRAINS

Identifying Valve Failures 3-1
Identifying Rocker Arm Failures 3-3
Identifying Push Rod Failures 3-4
Identifying Valve Tappet Failures 3-4

Chapter 4 — TURBOCHARGERS

Wheels and Impellers 4-1
Shafts 4-2
Journal Bearings 4-3
Thrust Bearings 4-5
Housings 4-5

Chapter 5 — GEARS

Introduction 5-1
General Category of Failures 5-2
Wear 5-2
Pitting, Spalling, and Case Crushing 5-3
Fatigue 5-5
Impact 5-7
Rippling, Ridging, and Cold Flow 5-7
Combined Effects 5-8
Specific Category of Failures 5-10

Chapter 6 — SHAFTS, AXLES, SPINDLES, AND UNIVERSAL JOINTS

General Category of Failures 6-1
Specific Category of Failures 6-4
Universal Joints 6-6

Chapter 7 — HYDROSTATIC TRANSMISSIONS

Thrust Plates Or Fixed Swashplate 7-1
Piston/Slipper Assembly 7-1
Slipper Retainer 7-3
Ball Guides 7-3
Cylinder Block 7-3
Bearing Plates 7-4
Bi-Metal Bearing Plates 7-5
Valve Plate 7-6
Shaft Seal 7-6
Charge Pump Assembly 7-7
Displacement Control Valve 7-7
Servo Sleeve And Piston 7-7
Shafts 7-8
Light-Duty Hydrostatic Systems 7-8

Chapter 8 — ANTI-FRICTION BEARINGS

Contamination 8-1
Improper Lubrication 8-2
Improper Installation 8-4
Carless Handling 8-4
Distortion and Misalignment 8-6
Severe Service 8-6
Vibration 8-7
Electric Current 8-7
Defects In Bearing Material 8-8

Chapter 9 — BELTS AND CHAINS

Introduction 9-1
V-Belts 9-1
Banded V-Belts 9-5
Special V-Belts 9-7
Flat Belts 9-7
Chains 9-8

Chapter 10 — TRACKS AND TIRES

Tracks 10-1
Special Tracks 10-2
Tires 10-3

Chapter 11 — MISCELLANEOUS FAILURES

Pump Rotors 11-1
Pump Impellers 11-2
Disk Blades 11-3
Spark Plugs 11-4

GLOSSARY 1

INDEX 5

PISTONS, RINGS, CYLINDER LINERS —Chapter 1

INTRODUCTION

Pistons, piston rings and cylinder liners are an essential part of an engine:

- *Pistons receive and transmit the force of combustion to the crankshaft*
- *Cylinder liners guide the piston*
- *Piston rings form a gas-tight seal between the piston and the cylinder.*

This section deals with identifying failures of these following components:

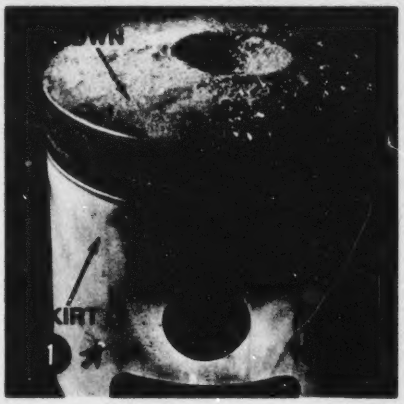
- **Pistons — gasoline engines**
- **Pistons — diesel engines**
- **Piston rings**
- **Cylinder liners**

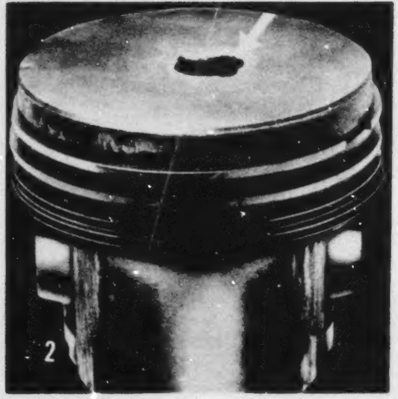
IDENTIFYING PISTON FAILURES IN GASOLINE ENGINES

Although some failures in pistons operating in gasoline engines are the same as in diesel engines, there are enough differences to justify separate groupings.

The principal causes of piston failures in gasoline engines are:

- **Detonation**
- **Preignition**
- **Scuffing and scoring**
- **Corrosive wear**
- **Physical damage to pistons**

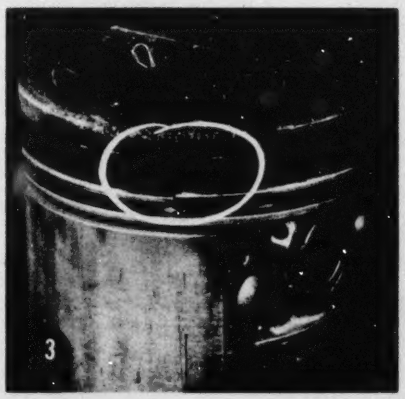


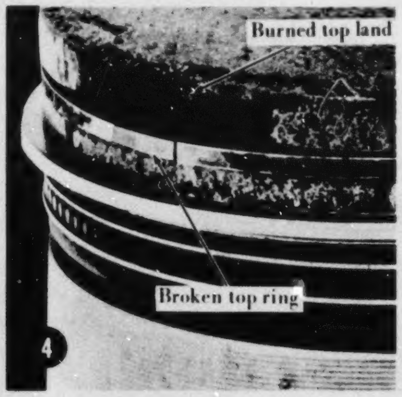


Detonation

Detonation is uncontrolled combustion accompanied by a loss of power and waste of energy. The piston is frequently damaged.

The pistons in Figs. 1 and 2 have been damaged by detonation. Because of the hammering pressures, piston damage usually appears as fractures on or through the crown, or in the skirt and piston pin area (large arrows in Fig. 1).

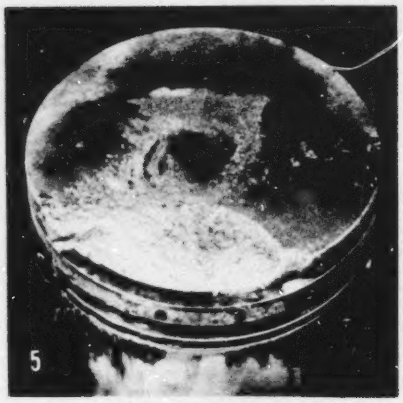


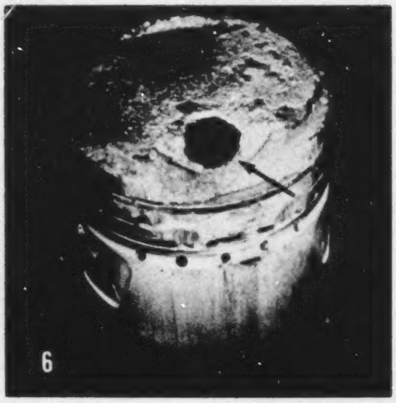


A noticeable knocking occurs when fuel in the cylinder ignites too early, too rapidly, or unevenly. The resulting "knock" can burn the piston, wear out the top groove, or cause the ring to break or stick (Fig. 3 and 4).

Causes of combustion knock:

- *Lean fuel mixtures*
- *Fuel octane too low*
- *Ignition timing advanced too much*
- *Lugging the engine or overfueling*
- *Cooling system not working (overheating).*





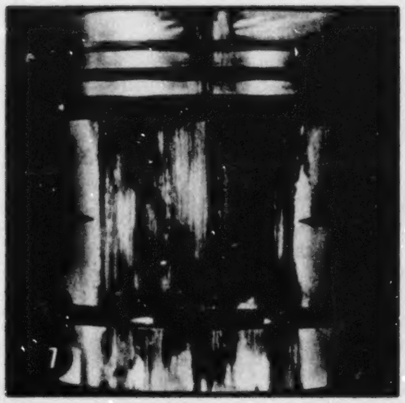
Preignition

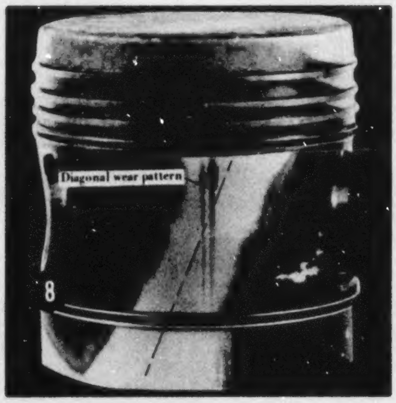
Occurs when the fuel ignites before the spark occurs. As a result, part of the fuel burns while the piston is still coming up on its compression stroke. The burning fuel is compressed and overheated by the piston, and by further combustion. The heat can get so intense that engine parts melt.

The pistons in Figs. 5 and 6 were damaged by the heat of preignition. The intense heat of preignition burned and melted the piston in Fig. 6. Damage may appear on and through the crown, through the ring lands, or both.

Causes of preignition:

- *Carbon deposits that remain hot enough to ignite fuel early*
- *Overheating*
- *Valve operating too hot because of excessive guide clearance or bad seats*
- *Hot spots caused by damaged rings*
- *Spark plugs of wrong heat range*
- *A loose spark plug*





Scuffing and Scoring

Scuffing and scoring (adhesive wear) is caused by too much heat. When two metal parts rub and the heat builds up to the welding point, a small deposit or "hot spot" of metal is pulled out and deposited on the cooler surface.

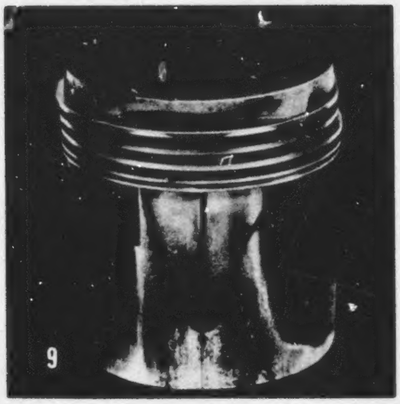
Scuffing leaves discolored areas on the surface of rings, pistons and cylinder walls.

Scuffing starts as tiny surface disturbances. If they are not removed, scuffing spreads and becomes noticeable and more severe. It is then called scoring (Fig. 7). Any engine condition which heats rubbing parts to the welding point, or which prevents the transfer of heat from these surfaces, influences scuffing.

The following are possible causes of scuffing and scoring:

- *Improper warm-up*
- *Lubricating system not functioning*
- *Cooling system plugged*
- *Combustion knock and preignition*
- *Lugging or overloading*

Occasionally an unusual wear pattern (Fig. 8) results from a misaligned connecting rod. Contact with cylinder wall shows on the bottom of the skirt at left, and at the ring lands on the right (arrows). There is also a diagonal wear pattern extending across the skirt of the piston. This uneven wear is due to a bent or twisted connecting rod or cylinder bored at an angle to the crankshaft. When connecting rods are misaligned, rings do not have proper contact with cylinder wall, pistons wear rapidly and unevenly, oil consumption is excessive and the engine is prone to scuff or score. Always check rod alignment.



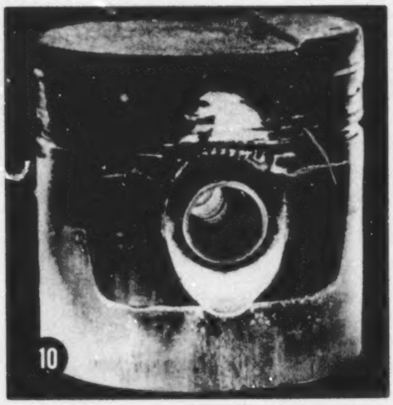
Corrosive Wear

Corrosive wear shows up as spotted grayish pitted surface on pistons or cylinder walls (Fig. 9).

The following are possible causes of corrosive wear:

- **Leaking coolant**
- **Cold engine operation**
- **Wrong lubricating oil**
- **Acids resulting from combustion**

Other corrosion may be harder to find. If excessive wear is found, and scuffing and scoring are eliminated as causes, suspect corrosive wear.



Physical Damage to Pistons

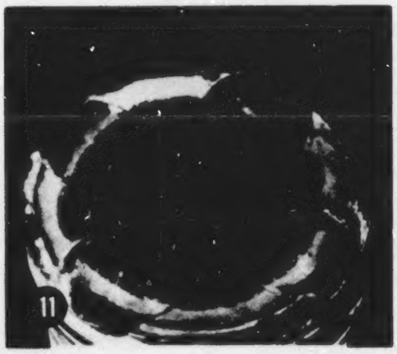
Physical damage to pistons can be caused by:

- *The piston losing its pin lock as in Fig. 10.*
- *Connecting rod out of alignment*
- *Crankshaft with too much endplay*
- *Crankshaft journal with too much taper*
- *Cylinder bore out of alignment*
- *Improperly installed piston pin locks*
- *Ring groove scratched while cleaning out carbon*
- *Piston handled carelessly or dropped*

IDENTIFYING PISTON FAILURES IN DIESEL ENGINES

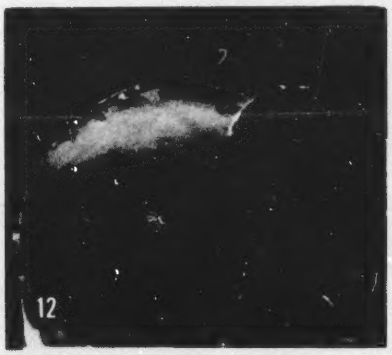
The principal causes of piston failures in diesel engines are:

- **Cracking**
- **Breakage**
- **Wear**
- **Scuffing and seizure**
- **Erosion**

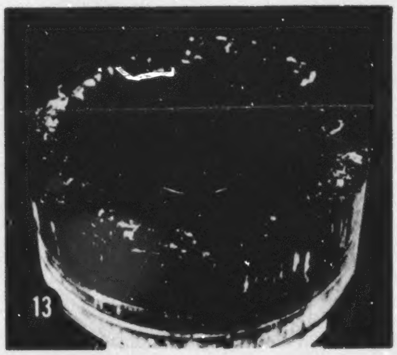


Cracking

Small hairline cracks will appear in the piston crater after normal operation. A piston with hairline cracks should be replaced. (Fig. 11).

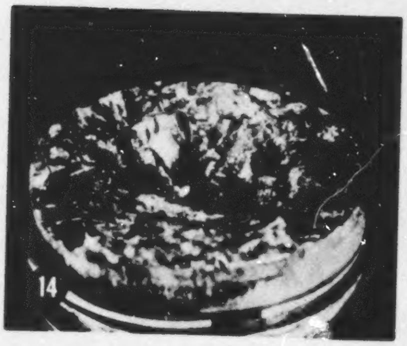


When crater cracks are open, deep, or interconnected, the piston top has overheated. Fig. 12 shows severe cracking.

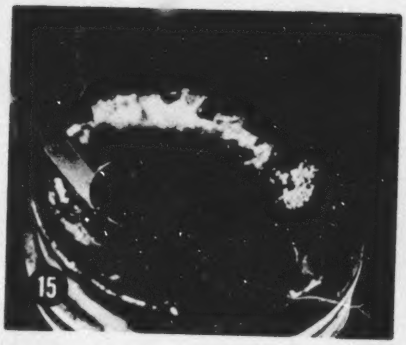


Piston Breakage

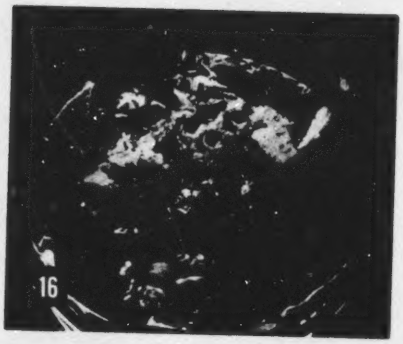
The piston in Fig. 13 was damaged by a broken glow plug tip. Tips break due to incorrect timing, shorting out, or rough combustion.



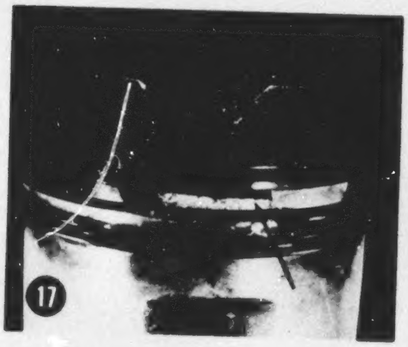
A broken valve damaged the piston in Fig. 14.



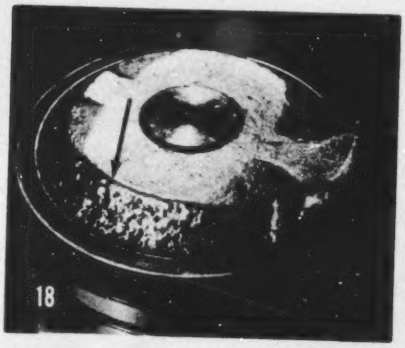
A loose heat plug eventually broke (Fig. 15) leaving a battered hole in the crown where it was located (Fig. 16). Note the impressions left by its threads in the top of the piston. Impressions give a clue to the cause of piston damage.



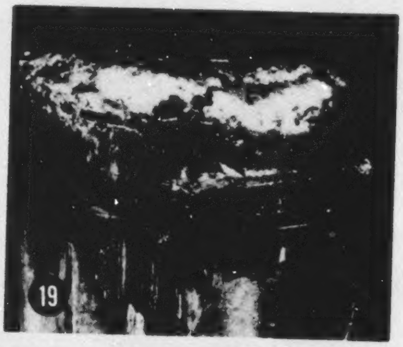
On rare occasions the bond between the piston and the cast iron insert, which holds the top ring, will fail. This type of failure probably occurs becuase of intense piston crown heat due to a constant overload operation or extreme load fluctuation.



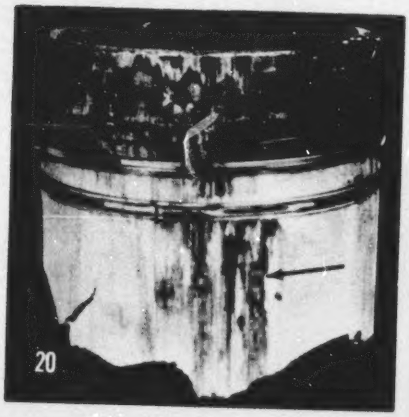
In Fig. 17 the iron insert has loosened and broke the ring land below it.



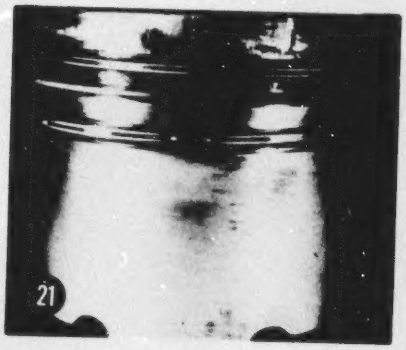
Under constant pounding the loose insert caused the outer edge of the piston crown to break away (Fig. 18).

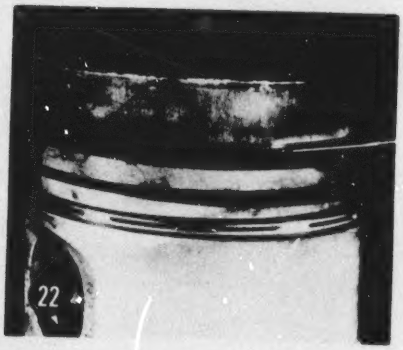


The broken insert continued to pound the piston, rounding off the edges of the insert retaining groove (Fig. 19).



Pistons usually break at the pin bore because of piston seizure—occasionally caused by overspeeding the engine. If piston seizure caused the breakage, the piston will bear extensive scuff marks (Fig. 20, arrow). If the broken piston is virtually unmarked, then breakage at the pin could be attributed to overspeeding. Overspeeding almost always shows evidence of piston hitting valve. Ether overdose, advanced timing, and overfueling are most common causes of piston breakage.



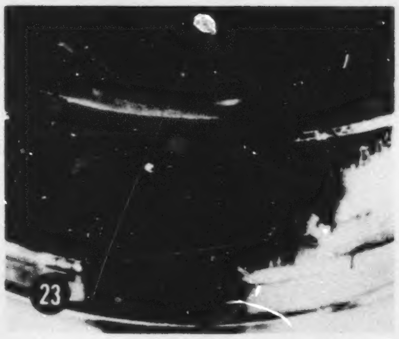


Wear

Wear produces a pattern similar to bearing wear—a shiny surface with many tiny scratches (Fig. 21) caused by the piston skirt occasionally contacting the liner. This slightly roughened surface aids in lubrication.

However, if pistons have any of the skirt damage mentioned below they should not be used again.

Abrasive wear is indicated by a piston skirt of a very dull gray, oil ring rails worn away, chrome facings worn off all rings, grooves badly worn, and some liner wear. Fig. 22 shows a piston badly worn by abrasives. Pistons like this cannot be reused. Dirt probably entered through the air inlet system and mixed with lubricating oil. Check piston-ring and ring-groove dimensions against technical manual specifications whenever the above conditions appear on the piston. An engine which shows piston and ring wear like this should be checked for leaks in the air inlet system.



Scuffing and Seizure

Scuffing and seizure are two related forms of piston damage: the first is usually mild and the second severely damaging.

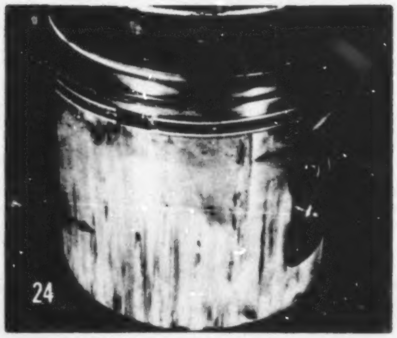
Scuffing on the top ring land (Fig. 23) can result when the piston top overheats and expands beyond its normal size. With metal-to-metal contact, the softer aluminum of the piston will pull away and stick to the liner wall.

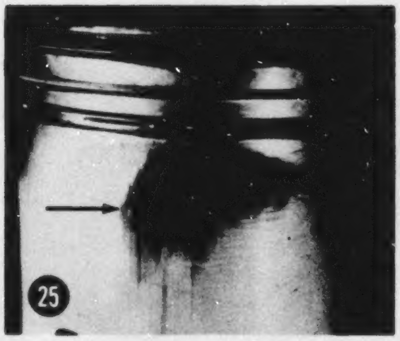
A leaking fuel valve or improper timing is the most common cause of the scuffing when it is confined to the first land. In an extreme case piston seizure will result.

Scuffing in streaks on the piston skirt — particularly in the pin bore area — with little or no scuffing on the first land may be caused by inadequate engine cooling (Fig. 24). If this type of damage appears on most or all of the pistons, cooling system failure or inadequate lubrication is the likely cause.

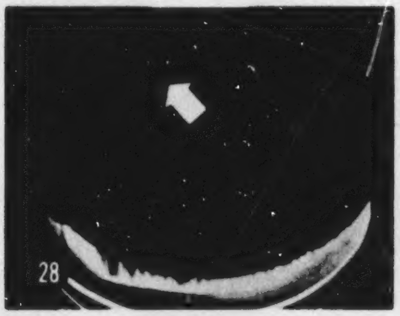
Check for:

- *Water or antifreeze leaks*
- *Crusty deposits in the ring lands, ring belt and crown of the piston*
- *Crankcase oil level*
- *Condition of the underside of the piston and the cooling jet*
- *Broken fan or water pump belt*
- *Plugged radiator*

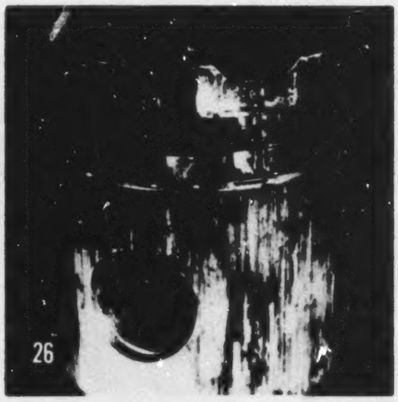




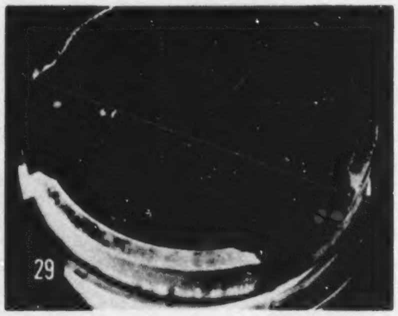
Small spots of skirt scuffing (Fig. 25) could be caused by abrasives from the crankcase oil, a bit of broken ring, or other material. Cold starts can also cause this type of scuffing, and it can occur due to inadequate lubrication in cold weather.



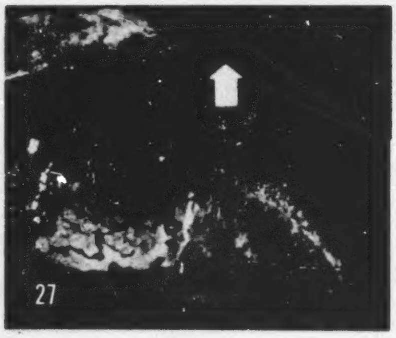
Inadequate air supply can cause rough combustion resulting in erosion of the piston top (Fig. 28 and 29).



Scuffing marks extending from the top to the bottom of the piston can indicate the piston was oversized. Cooling or lubrication system failures can also produce full length scuffing (Fig. 26).

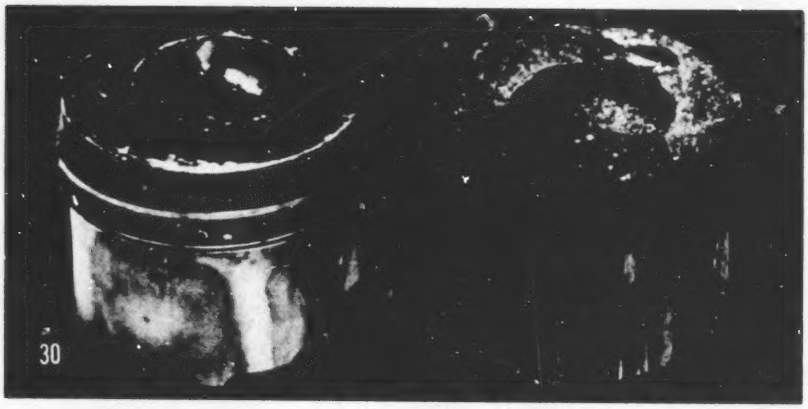


In this case, erosion is more uniform around the outer edge of the crater and is located away from the inlet valve pocket. Check for restrictions or leaks in the inlet air system.



Erosion

Erosion of the piston top is generally caused by rough combustion. When valve pockets are eroded (Fig. 27), a leaking fuel valve or incorrect timing is the likely cause. When the fuel burning cycle is not normal, incomplete or "rough" combustion occurs. This causes high peak pressures and excessively high temperatures which could damage the piston crown. Check the fuel injection nozzles and engine timing.


30

Another example of crown erosion is illustrated in Fig. 30. The condition of the blackened piston on the left and the eroded piston on the right was caused by burning liquid fuel.

Advanced timing or high altitude operation without derating the engine can cause fuel to collect on the top of the piston resulting in severe erosion. This leads to piston seizure.

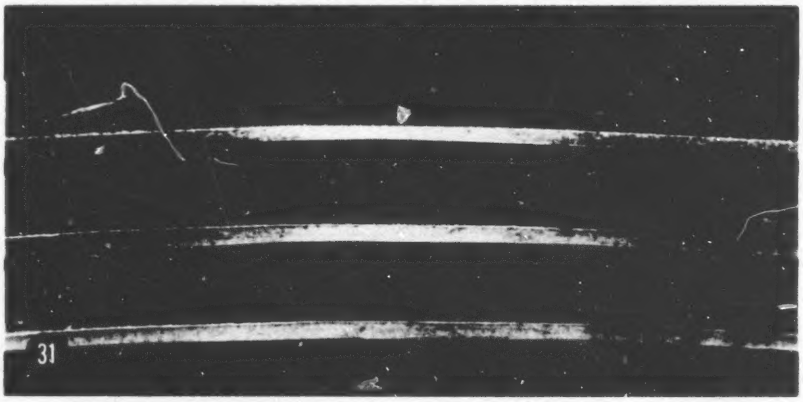
IDENTIFYING PISTON RING FAILURES

Piston rings do three jobs:

- *Form a gas-tight seal between the piston and cylinder*
- *Help cool the piston by transferring heat*
- *Control lubrication between piston and cylinder wall*

The principal causes for failure of piston rings are:

- **Wear**
- **Chipping**
- **Scuffing and scoring**
- **Breakage**
- **Sticking**


31

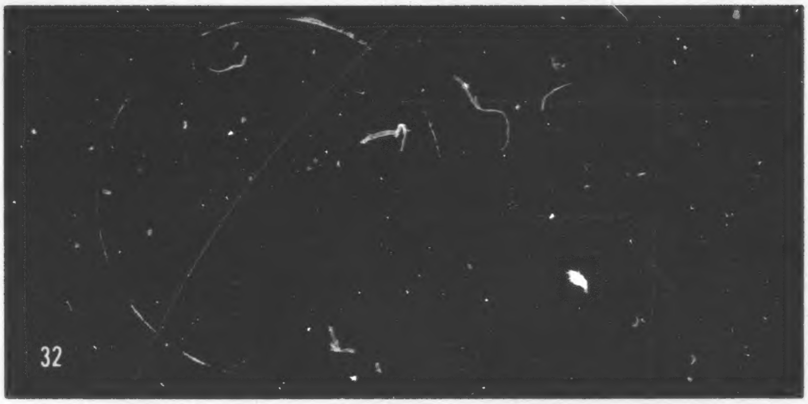
Wear

When the ring faces are covered with dull gray, vertical scratches and have excessive ring-to-groove clearance, the rings have been worn by abrasives. See Fig. 31.

Other indications of abrasives in the engine are dull gray vertical scratches on piston skirts, scratched cylinder bore, high ridge at the top of the cylinder, loose piston fit, or badly scratched rod and main bearings.

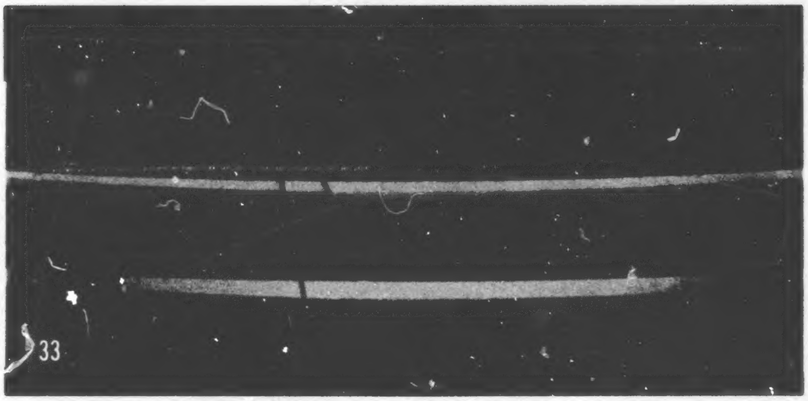
10

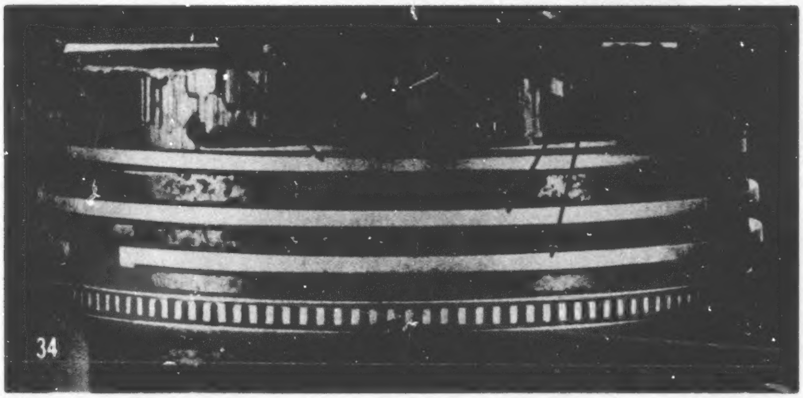
Badly worn compression ring is shown at left in Fig. 32. A new ring is at right.

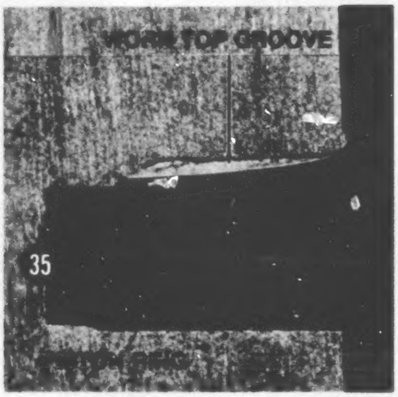


Vertical scratches across the faces of rings, as shown in Fig. 33, are caused by airborne abrasive or abrasives left in the engine at the time of overhaul.

Unless the source of the abrasives is found and corrected, the life of any new ring set will be short.





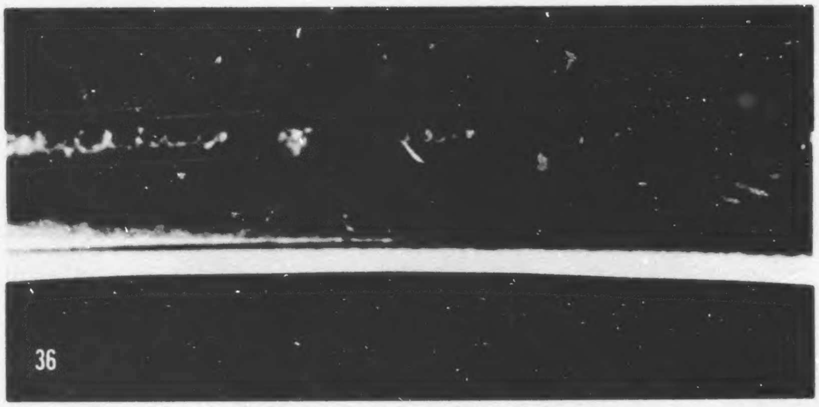


Common causes for abrasives in an engine are:

- *No air cleaner*
- *Failure to service air cleaner at regular intervals*
- *Loose connections between air cleaner and intake manifold*
- *Holes in tubing*
- *Damaged filter element or housing, permitting unfiltered air to go around filter element*
- *Failure to properly clean cylinder bores*

Fig. 34 shows rails of the oil ring worn down to the steel expander spacer as well as substantial wear of the spacer. The spacer can wear in this manner only from cylinder wall contact. An oil ring worn in this manner can no longer provide oil control.

Many aluminum pistons removed for re-ring installation have excessively worn top grooves as shown in Fig. 35. This area wears most because it is exposed to maximum combustion heat and pressure and all airborne abrasives that enter the engine. See Technical Manual for specification.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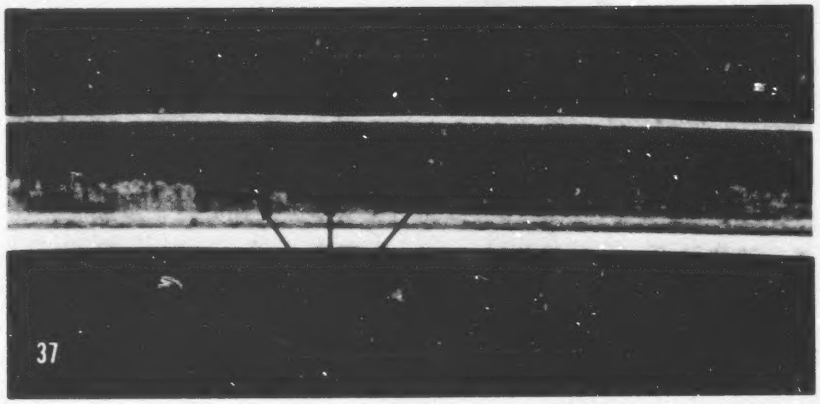
Chipping

Chrome can be chipped from rings by careless handling or incorrect ring compressors. Rings can also be chipped during operation by incomplete combustion. (Fig. 36).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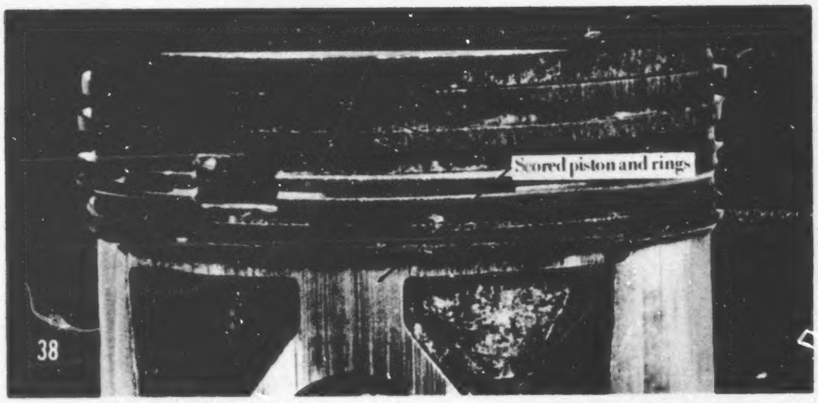
Scuffing and Scoring

Ring scuffing resembles piston scuffing. Small amounts of ring material have pulled away and stuck to the liner (Fig. 37).



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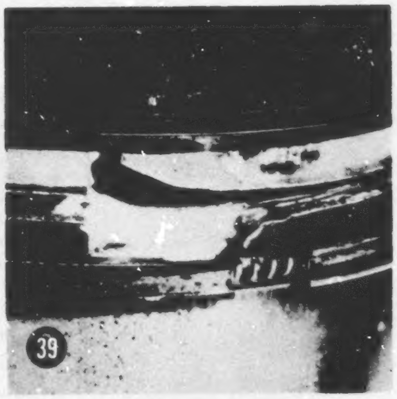

39

Scoring is a more severe form of scuffing. Both the rings and the piston in Fig. 38 are scored. When metal-to-metal contact occurs between the two rubbing surfaces and the temperature of one of these surfaces reaches the welding point of the material, scoring will result.

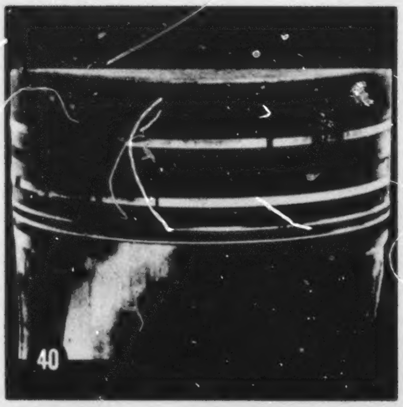
Causes of scuffing and scoring are:

- *Overheating due to a faulty cooling system*
- *Lack of cylinder lubrication*
- *Improper combustion*
- *Incorrect or insufficient bearing or piston clearances*
- *Improper break-in*
- *Coolant leakage into cylinder*
- *Overfueling*

Breakage

When a ring breaks, the pieces bounce around in the groove causing severe erosion of the land and some scuffing on the piston crown or skirt. In Fig. 39, a broken ring caused erosion of second and third lands which look "melted" away.

One of the major causes of ring breakage is incorrect installation. Expanding the ring by hand or using the wrong sized expander can fracture a ring, breaking it into pieces during operation. Ring breakage also occurs when the groove has worn too wide or is filled with carbon.



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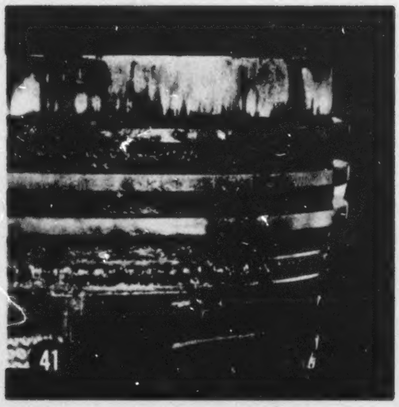


41

Sticking

Deposits caused by too much heat, unburned fuel and excess lubricating oils collect in the piston ring area. Ring failure usually occurs when these deposits harden and freeze the rings in their grooves.

When the rings are completely stuck they often break (Fig. 40).

Deposits on the top ring groove cause sticking, scuffing and scoring because they keep out oil and trap metal particles that wear off the piston.

Sludge deposits in the oil control ring cause it to plug (Fig. 41). This means that oil control has been lost.

Other conditions that lead to stuck or plugged rings are:

- **Plugged air cleaner**
- **Excessive idling**
- **Top groove failure**
- **Cylinder liner distortion**
- **Combustion knock (gasoline)**
- **Preignition (gasoline)**
- **Overloading**
- **Cooling system failure**
- **Improper lube oil**
- **Cold engine operation**
- **Overfueling**

42

IDENTIFYING CYLINDER LINER FAILURES

The principal causes of failure of wet cylinder liners are:

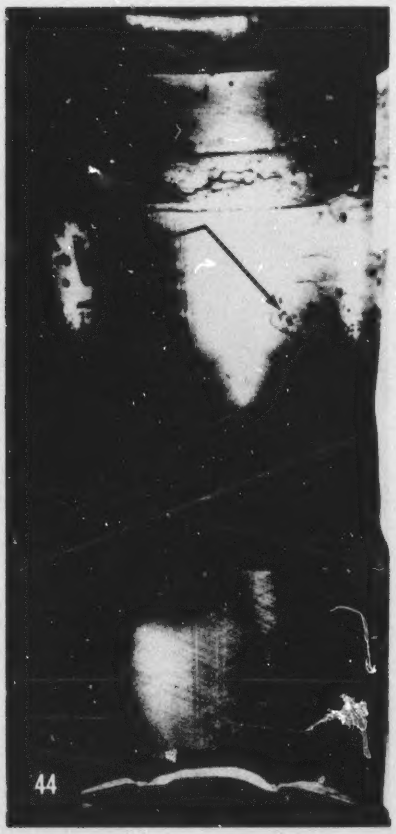
- **Cracking**
- **Chemical attack**
- **Cavitation**
- **Wear**

Cracking

The failure in the liner in Fig. 42 consisted of a lengthwise crack originating at the flange and extending downwards below the ring travel area. Apparently water penetrated into the liner, probably as a result of a leaky head gasket and promoted the crack of the liner during compression stroke.

43

The failure in the liner in Fig. 43 consisted of a crack directly below the flange that penetrated across the section to the top side. The liner could have cracked in overhaul of the engine. The damage may be due to dirt in the counterbore of the block, under the flange, causing uneven loading.



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Chemical Attack

Distinct etch marks (corrosion) in the ring travel area of the wear surface in Fig. 44 are visible. This is the result of the corrosive action of the coolant. The piston usually is scored before the corrosion appears.

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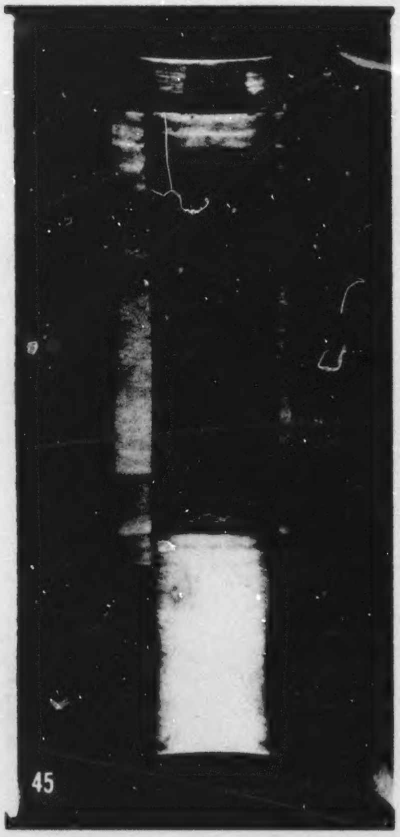

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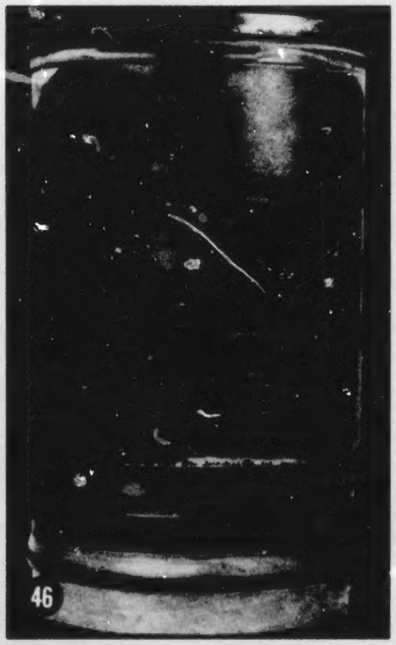
The apparent crack in Fig. 45 is actually a line caused by chemical attack.



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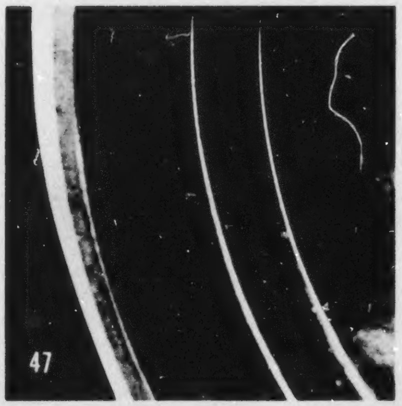
Cavitation

Cavitation occurs when bubbles violently collapse against the coolant side of the liner. (Fig. 46). Such action is accelerated by impurities and lack of proper rust inhibitors in the coolant.



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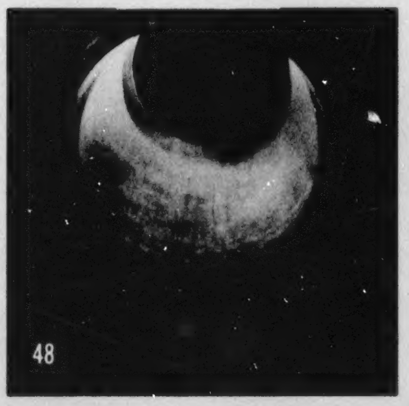
Wear

Wear steps are often visible in used liners (Fig. 47) and normally should be replaced. If clearance between piston and liner is within service specification, and if liner is not otherwise damaged, the liner may be re-useable.



48

Scratching

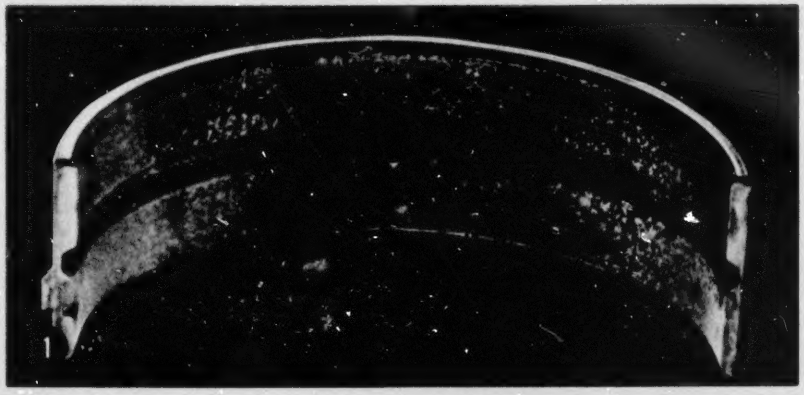
Scratching occurs when dirt particles enter the engine. During operation the dirt moves between the liner and piston rings causing scratches (Fig. 48).

JOURNAL BEARINGS — Chapter 2

INTRODUCTION

When replacing damaged bearings it is vital to determine the cause to prevent repeated failure. Most failures are due to the following causes:

- **Dirt**
- **Lack of lubrication**
- **Improper assembly**
- **Misalignment**
- **Overloading**
- **Corrosion**
- **Electric current**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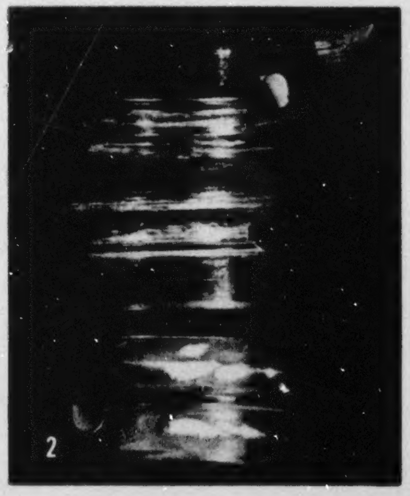
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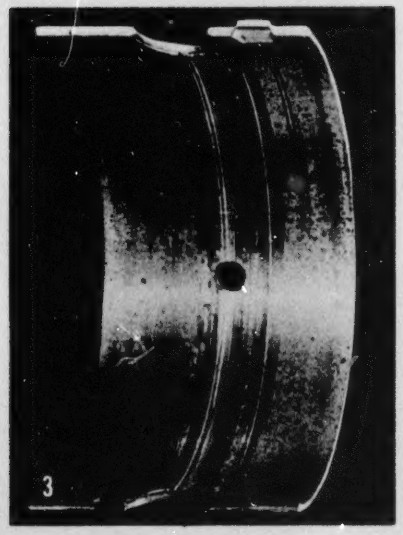
Dirt

Large dirt particles can embed in the soft bearing material (Figs 1, 2, and 3). This causes wear and decreases the life of both the bearing and its journal. Prevent this by cleaning the area surrounding the bearing thoroughly during installation and by proper maintenance of any air and oil filters.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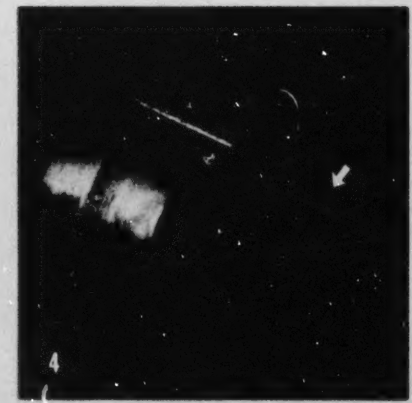
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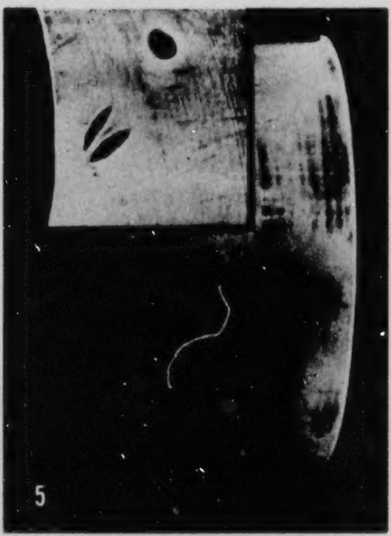
Figures 4 and 5 show when a particle of dirt was left during bearing installation; it caused damage by pushing the bearing inward increasing localized pressure and heat.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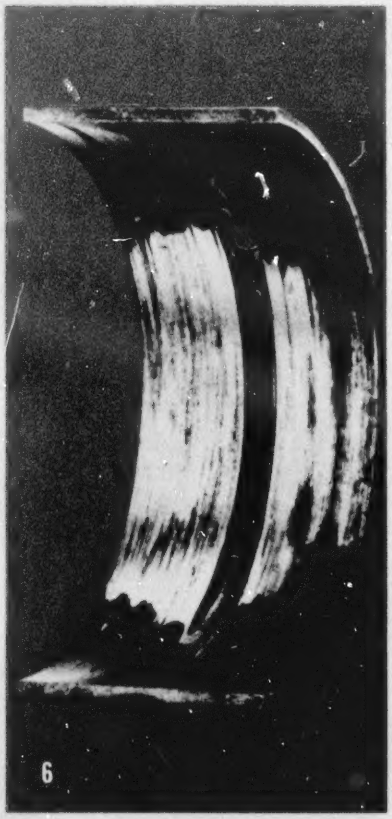
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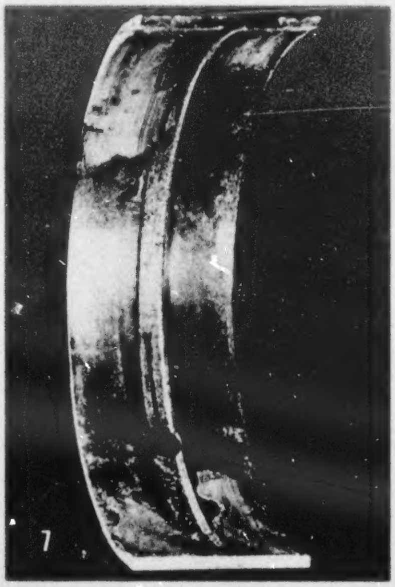

7

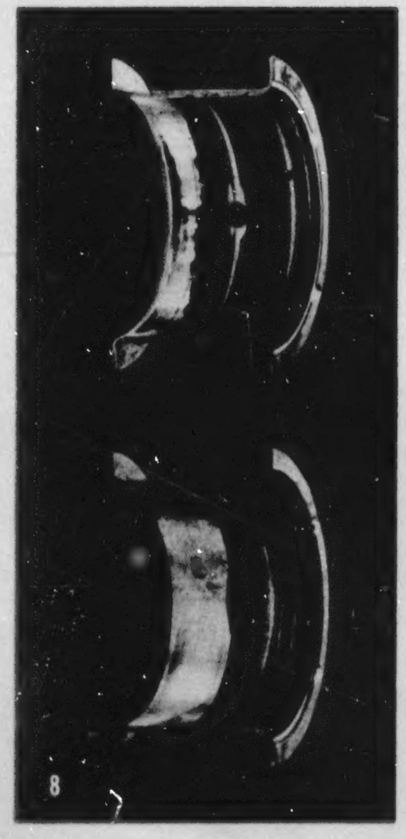
Lack of Lubrication

Oil starvation damaged the bearing shown in Figures 6 and 7. Lack of oil can occur immediately after overhaul, when priming of the lubricating system is vital.

After break-in, other things can happen. Both local and general oil starvation can result from external leaks. Blocked oil suction screen, oil pump failure, plugged or leaking oil passages, failed relief valve springs, or badly worn bearings can stop the circulation of lubricating oil.

A mislocated oil hole will also cut off the oil supply to a bearing, causing rapid failure. Always check to be sure the oil hole in the bearing is in line with the oil supply hole.

Also, in the case of engines, the oil supply may become diluted by seepage of fuel into the crankcase from a failed fuel pump. This will reduce the oil's film strength and the friction will score the bearings.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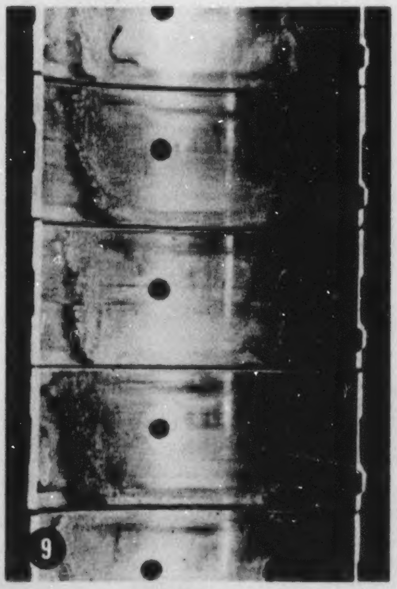

9

Improper Assembly

Improper assembly and the resultant damage to the bearing can be due to tapered journals, out-of-round bearing bore, incorrect crush, or rod misalignment.

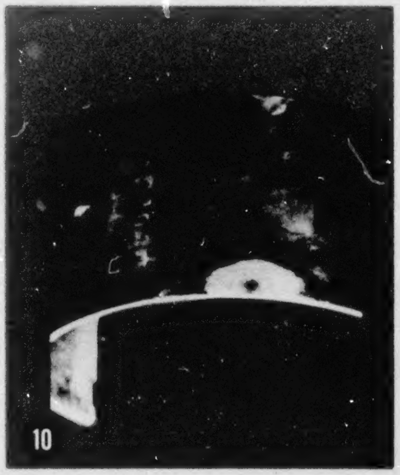
Tapered journals allow areas of excessive clearance between the journal and bearing distributing more wear on one edge of the bearing (Fig. 8). This wear is increased by the force on the bearing carrying the greater load.

Out-of-round bearing bore (Fig. 9) usually is visible by lining wear pattern at parting edges, so high wear rate and heat takes place in this area.

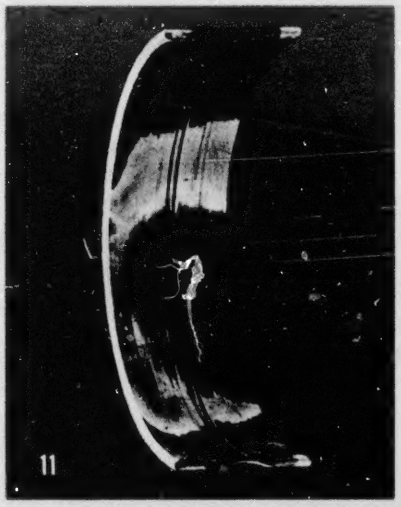
A small amount of the bearing insert extends beyond parting edges of the rod and rod cap. When the rod bolts are tightened, the bearing inserts are seated. This condition is called crush. Crush built into the bearing inserts by bearing manufacturers is determined by experience and engineering data, and should under no circumstances be altered. As recommended torque value is applied to the bearing halves, a squeezing action takes place due to correct crush being present at parting edges. This pressure holds the inserts secure in correct position.

Excessive crush frequently results when someone files parting edges of bearing caps. Excessive crush brings about inward collapse of the bearing insert resulting in premature bearing failure and crankshaft damage.

The opposite of excessive crush is insufficient bearing crush (Fig. 10) which can result in destructive action to both bearing and crankshaft. Any polished area on bearing insert back, or at parting edges, is a true indicator of insufficient crush. Polishing action is caused by bearing movement in bearing bore. Insufficient crush causes loss of heat transfer and bearing lining failure. A few causes of insufficient crush are:



- *Insufficient torque due to damaged mating surfaces at parting edges of caps and bores*
- *Capscrews bottoming in blind threads, resulting in false torque reading*
- *Bearing bore wear or cap stretch*



Misalignment

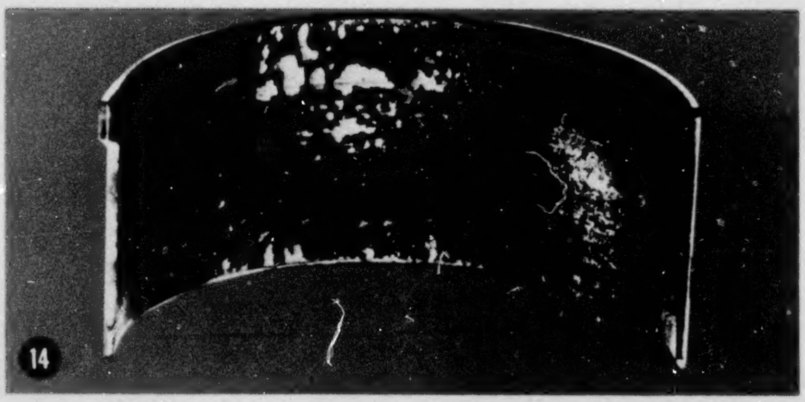
Heavy wear on outer edges of upper and lower bearing inserts (Fig. 11) could indicate misaligned connecting rod. Misalignment is caused by:

- *Operational abuse such as excessive lugging*
- *Faulty connecting rod installation*
- *Abuse of connecting rod in work area prior to assembly in engine*

Misalignment can cause concentrated wear on the bearings (Fig. 12) — one edge of the upper bearing and the opposite edge of the lower bearing. When this wear pattern exists, check the alignment of the shaft and bearings.

Overloading

Overheating from overloads causes a metal fatigue which breaks away from the surface of the bearing (Fig. 13).



14

Corrosion

Corrosion from acid formation in the oil causes finely pitted surfaces and large areas of deterioration (Fig. 14).

Corrosion occurs when oil temperature goes very high and when excessive blow-by occurs in engines. Condensation and, in some cases, incorrect lubricant will also cause corrosion.

Prevent corrosion in engines by changing oil at correct intervals and by selecting oil of the proper quality and classification for the machine and type of service. Follow the manufacturer's recommendations.

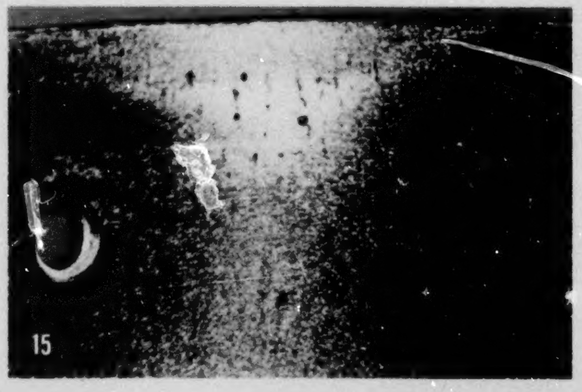


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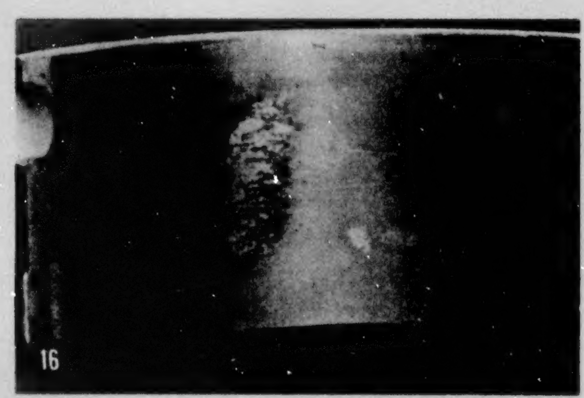
Fig. 15 shows corrosion of the lead in a copper-lead bearing. Probably the biggest source of corrosive attack is the oxidation products formed in oil itself.



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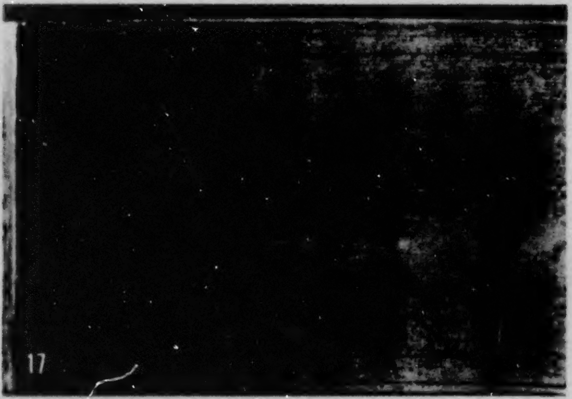
Erosion consists primarily of a mechanical washing away of the bearing surface by the oil stream between the journal and the bearing. The formation and collapse of air bubbles within the oil can lead to extremely high localized pressure which result in localized fatigue and pitting of the bearing surface by "cavitation erosion" as shown in Fig. 16.



17

Electric current

Destructive current may cause sparks to pass through the oil film. This, in turn, produces microscopic pits in the surface of the journal and the bearing. This action results in a continual removal of metal from the surface of the bearing. Troubles may be noticed in periods ranging from a few hours up to several years, depending upon the magnitude of the current flow.

Electrical wear shows up as a frosted surface (Fig. 17) in the loaded zone of the bearing.

VALVE GEAR TRAIN — Chapter 3

INTRODUCTION

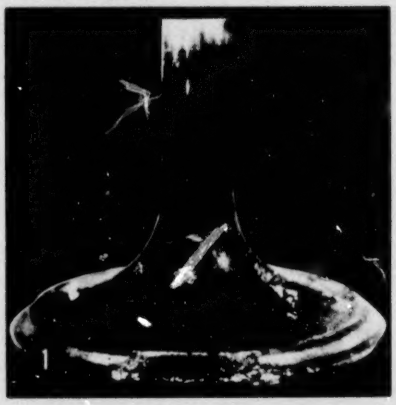
The valve gear train in a typical engine consists of the camshaft, tappets, push rods, rocker arms, valves and valve spring. The failure of these parts are described in this section.

IDENTIFYING VALVE FAILURES

Of all the components of the valve gear train, valve failures, particularly exhaust valves, represents the more common problem.

The major causes of valve failures are:

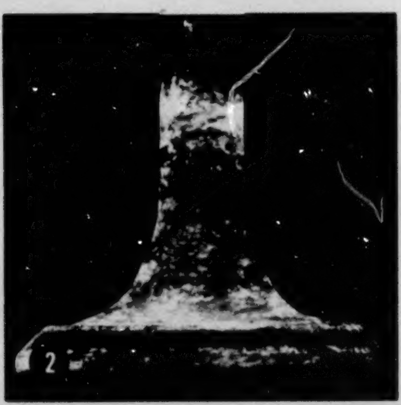
- **Distortion of the valve seat**
- **Deposits on valve**
- **Too little tappet clearance**
- **Scuffing of stem**
- **Erosion**
- **Heat fatigue**
- **Breaks**
- **Wear**

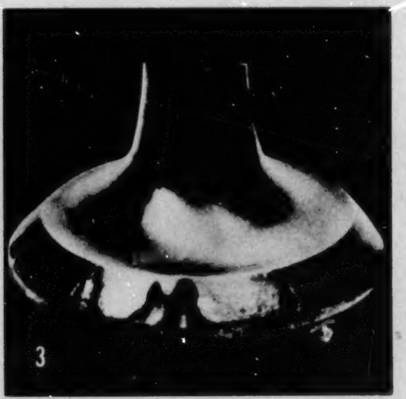


Distortion of Valve Seat

The valve in Fig. 1 is burned because of distortion of the valve seat. Major causes of seat distortion are:

- *Failure in the cooling system*
- *Out-of-round or loose seat. This may stop the transfer of heat between the insert and the head or block.*
- *Warped sealing surfaces on heads or blocks often distorts the seats when the head is tightened. Improper tightening, too much torque and the wrong sequence can also distort valve seats.*
- *Failure to grind the valve seat concentric with the valve guide hole.*





Deposits on Valve

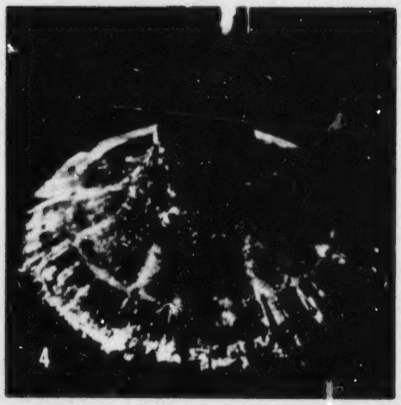
Deposits are not typical causes of failure in diesel engines, but do occur.

Deposits on the valve stem (Fig. 2) result from too high a valve stem temperature for the oil being used. There was an apparent lack of heat flow from the valve stem to the guide and from the guide to the cylinder block. The heat apparently was trapped in the guide, resulting in excessive carbon formation.

The valve in Fig. 3 failed because face deposits built up and then broke off. This damaged the seat and the resulting "blow-by" burned the valve.

Other factors that may cause this type of failure are:

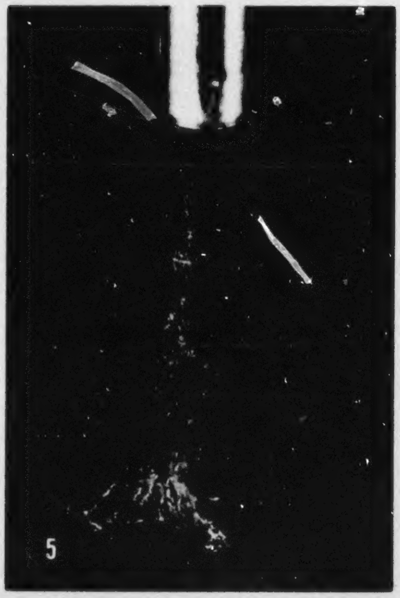
- *Weak valve spring causes a poor seal between the seat and the face, allowing deposits to form.*
- *Too little tappet clearance also causes a poor valve-to-seat seal.*
- *Valves sticking in the valve guide allows deposits to build up on the valve face and seat.*
- *Valve seats that are too wide cut down the seating pressure and reduce the crushing of deposits when the valve closes.*
- *Lack of valve rotation (which is needed to "scrub" the valve).*



Too Little Tappet Clearance

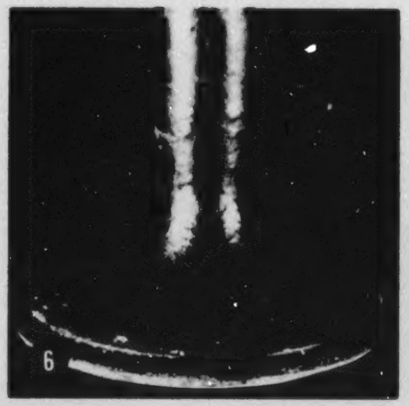
Failure of the valve in Fig. 4 was caused by too little tappet clearance. The valve was held off its seat and blow-by caused face-burning. Causes of too little tappet clearance are:

- *Tappet clearance not set to specifications*
- *Failed valve rotators and, as a result, burned valves*
- *Cooling system not operating properly or wrong thermostat*
- *Extremely high temperatures affect tappet clearance*
- *Tappet clearance not rechecked after break-in and retightening of head*



Burned Valve

The valve in Fig. 5 burned and failed as a result of preignition. Valve temperature became so high that part of valve face melted away.

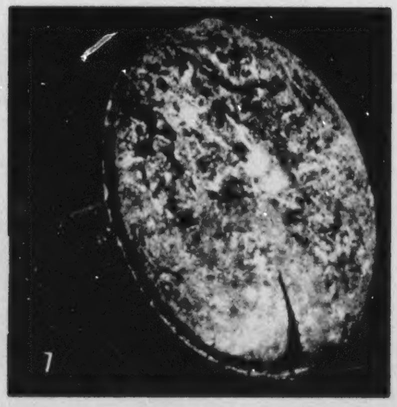


Erosion of Valves

The valve in Fig. 6 is eroded, but has not failed. However, it would have broken after much more service because of the erosion under the head.

Causes of valve erosion are:

- *Wrong type of fuel*
- *Faulty combustion*
- *Too high valve temperatures*
- *Lean fuel air mixtures which overheat valves and erode them*

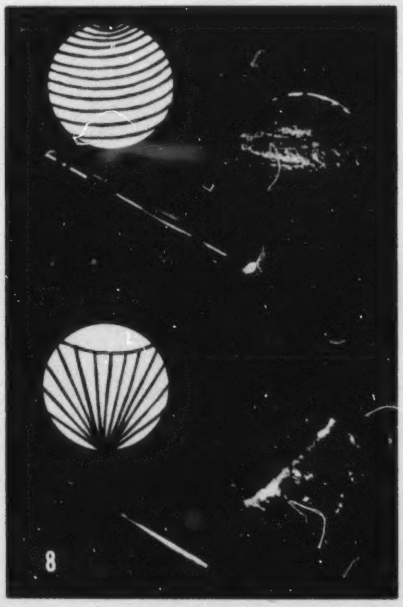


Heat Fatigue

Overheating can crack the valve head (Fig. 7). More cracking may cause parts of the valve to break off.

Causes of cracked valves from heat fatigue are:

- *Worn guides*
- *Distorted seats*
- *Lean fuel-air mixtures*



8

Breaks

Fatigue break is the gradual breakdown of the valve due to high heat and pressure. A fatigue break usually shows lines of progression as at the top in Fig. 8.

Impact break is the mechanical breakage of the valve. The cause is seating the valve with too much force, often caused by too much valve clearance. An impact break does not show the lines of progression, but rather the familiar crow's-feet (see bottom, Fig. 8).

Broken valves are not always clearly one type or the other. Combinations of heat and high seating force can produce failures of varying degrees and appearance. Fig. 8 shows the differences between fatigue and impact breaks.

9

Wear

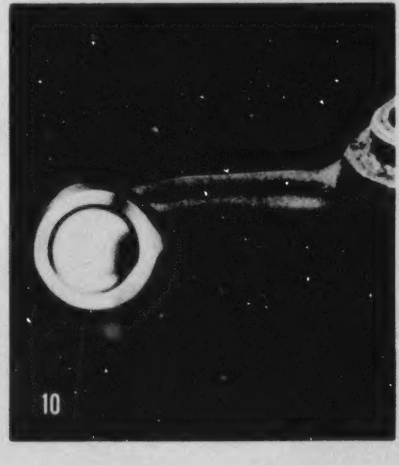
The valve shown in Fig. 9 failed because of face burning. Wear on the stem and carbon projecting into the guide shows the valve guide was worn and was the likely cause of the failure.

Worn valve guides lead to valve failures:

- *Worn guides prevent even grinding of the valve seat leading to out-of-square seating, which allows burning gas to leak out and burn the valves.*
- *Worn guides cause the valves to strike at an angle and damage the sealing surface leading to blow-by and burning.*
- *Excessive stem-to-guide clearance allows too much oil to run down the stem, resulting in excessive carbon deposits that cause valve sticking.*
- *When the inside edges of the valve guides wear, they can no longer act as carbon scrapers.*

Other factors can also cause valve guides to fail prematurely:

- *Worn rocker arms cause excessive side thrust on the valve stem*
- *Poor lubrication results in scoring*
- *Carbon deposits on the valve stem wear the valve guide into a bell-mouthed shape*
- *Cocked valve spring places side thrust on the valve stem, and results in excessive wear*



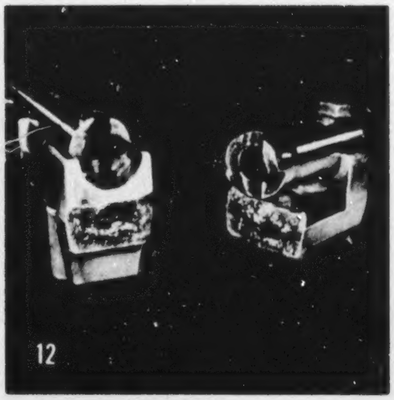
10

IDENTIFYING ROCKER ARM FAILURES

An example of poor lubrication on rocker arm tip wear is shown in Fig. 10. The rocker arm tip in this case was worn approximately 1/32" deep. The effect of this condition would:

- *Upset valve motion*
- *Contribute to side thrust of the valve, thus aggravating guide wear*
- *Make lash adjustment with a conventional feeler gage difficult*

11



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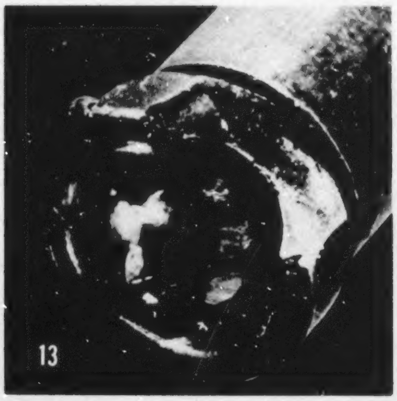


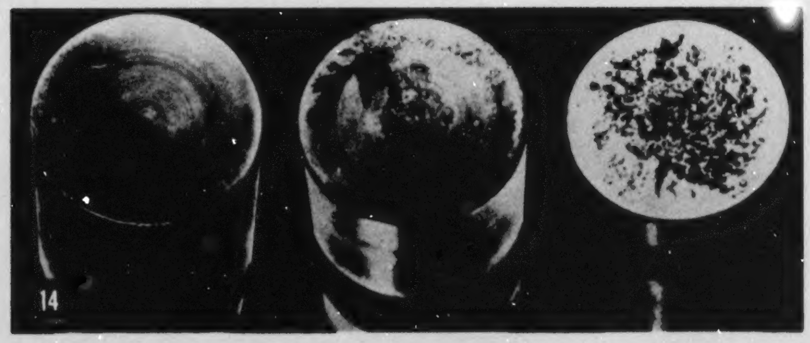
13

Loose rocker arm bracket bolts allowed the rocker arm shaft and bracket in Fig. 12 to bend and break. Whenever the rocker arm shaft is installed, the mounting bolts should be tightened to the specifications in the technical Manuals. Scuffed rocker arm balls at the push rod and rocker arm tips also result in failures.

IDENTIFYING PUSH ROD FAILURES

When a push rod cup is worn or broken it also can cause valve failure. The rod in Fig. 13 has a broken cup caused by misalignment of the push rod with rocker arm adjusting screw. Careful reinstallation of the rocker arm assembly prevents this.

Spalled rocker arm inserts are shown in Fig. 11. Spalling results from heavy loading and repeated contact between moving parts.



14

IDENTIFYING VALVE TAPPET FAILURES

Because of heavy loads and high speeds in engine operation, valve tappets may show signs of wear, scuffing and surface fatigue (Fig. 14). Wear is a gradual, smooth loss of surface material by friction (left). Scuffing is a more severe form of wear (center). The deterioration is characterized by deep grooves, rapid surface roughening, welding and tearing away of the surface metal. Surface fatigue is a tendency of a metal chip to break under stress conditions (right). It is frequently referred to as pitting, spalling and flaking. Dust in the oil causes abrasive wear.

TURBOCHARGERS — Chapter 4

INTRODUCTION

This section deals with identifying failures of the following turbocharger components:

- **Wheels and Impellers**
- **Shafts**
- **Journal Bearings**
- **Thrust Bearings**
- **Housings**

These failures are discussed and illustrated on the following pages.

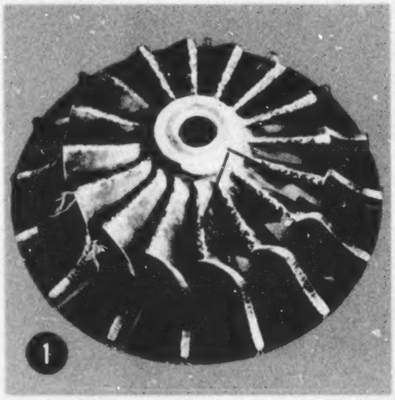
Important: In almost all cases, replacing a failed part will not, in itself, correct the failure. To avoid repeated failures, determine and correct the cause of failure.

WHEELS AND IMPELLERS

High rotational speeds and high temperatures make the turbocharger wheels sensitive to abusive environmental and operating conditions.

The causes of turbocharger wheel failures are described below:

- *Foreign material (a major cause of failure)*
- *Contact damage*
- *Erosion or abrasion*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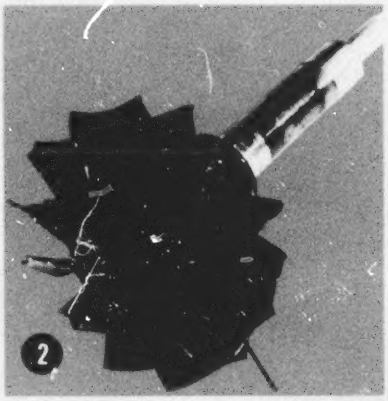
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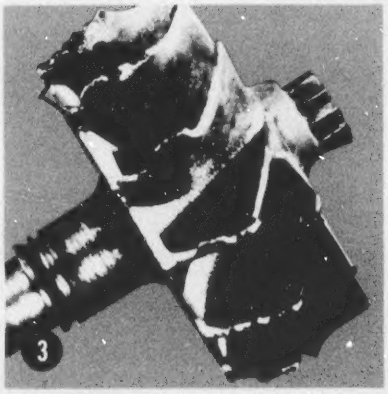
Foreign Material

Foreign material is a major cause of turbocharger failure. Foreign material in the intake system may lead to the type of damage in Fig. 1. Badly nicked edges of the compressor wheels were probably caused by:

- *Welding slag not removed from duct*
- *Loose wire particles from the air cleaner*
- *Nuts, bolts, washers, etc.*
- *Particles left from previous turbocharger failures*
- *Compressor wheel nut loosened and backed off threaded shaft*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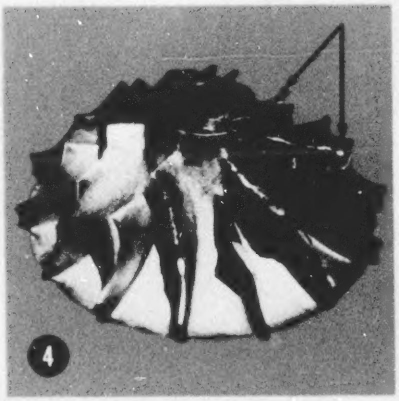
Foreign material in the exhaust system damaged the turbine wheels in Figs. 2 and 3. Probable causes of blade tips chewed, battered, deformed and broken off are:

- *Loose material in exhaust manifold (nuts, bolts, washers and pieces from previous turbocharger failure)*
- *Engine valve breakage*
- *Piston ring breakage*

24

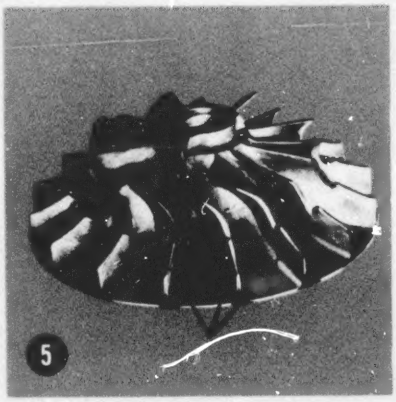


4

Contact Damage

Damage to bearings from contaminated lubricant or from lack of lubricant will allow motion of the shaft. This may permit the compressor wheel or turbine wheel to contact their respective housings. This could also be caused by an imbalanced rotating assembly.

Fig. 4 is a severe example. Finding more than one blade broken with heavy rubbing on adjacent blades gives evidence that blade breakage followed, rather than caused, the contact damage.



5

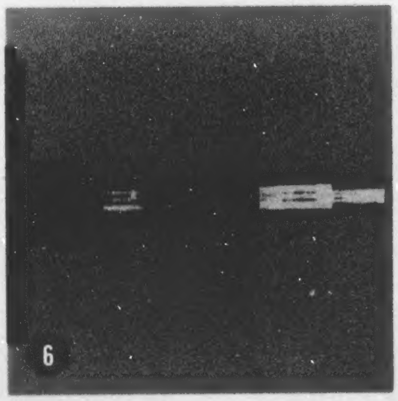
Abrasion-Erosion

Sand caused the impeller erosion in Fig. 5. Note the nicked leading edges, blade tips thinned from sand or other hard particles striking the blade surface at a high rate of speed, and blade contour deeply eroded.

SHAFTS

The modes and causes of turbocharger shaft failures are described below:

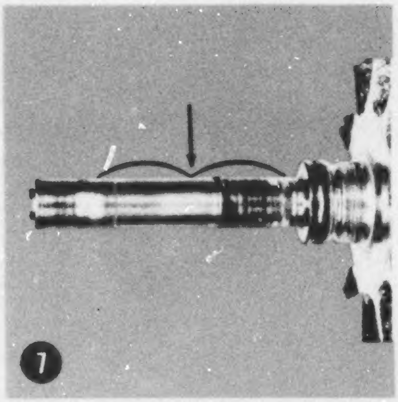
- *Oil starvation (a major cause of turbocharger failure). If an engine is shut off immediately, without cooling down, the turbocharger "free-wheels" to a stop and receives no lubrication. Allow the engine to run for a short time at low idle before shut off.*
- *Contaminated oil*



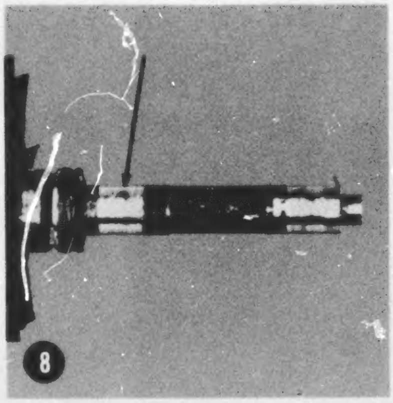
6

Oil Starvation

Start-up and shut down procedure is important especially after an engine has not been used for several weeks, or after an oil change. Momentary oil starvation can cause bearing material to rub off (arrow, Fig. 6) on the shaft and cause shaft vibration.

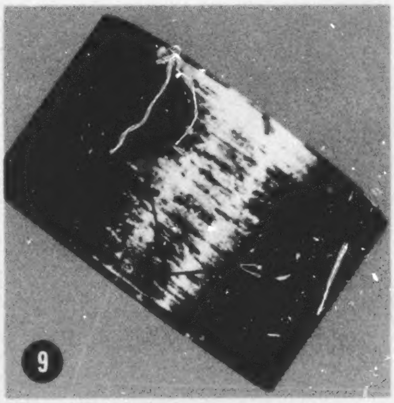


A momentary loss of oil can also cause blueing of the shaft (Fig. 7) a sign of overheating.



Contaminated Oil

Contaminated oil can damage internal parts of a turbocharger. Scratched and worn bearing surfaces (Fig. 8) will cause drag and unbalance the rotating assembly ending in turbocharger failure.



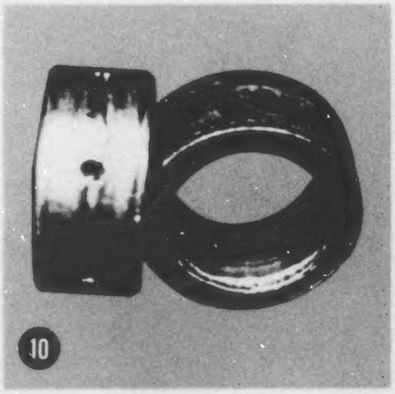
JOURNAL BEARINGS

The principal causes of journal bearing failures are:

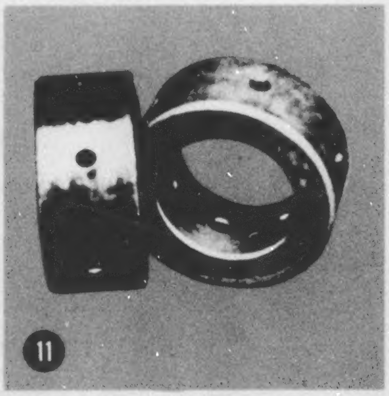
- *Oil starvation - (Note–a major cause of turbo failure). Engines must be run for a short time at low idle speed before being shut off. This allows turbocharger and engine components to cool down before the oil supply is cut off.*
- *Contaminated oil*

Oil Starvation

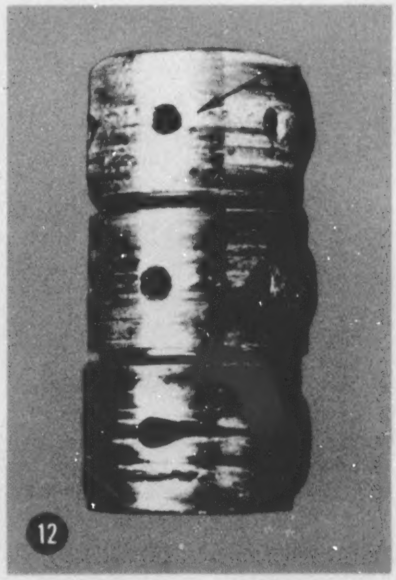
Lack of lubricant caused the bearing material in Fig. 9 to deform (oil holes beginning to fill in).



Inadequate lubrication caused the bearing in Fig. 10 to look spotty with fine scratches.

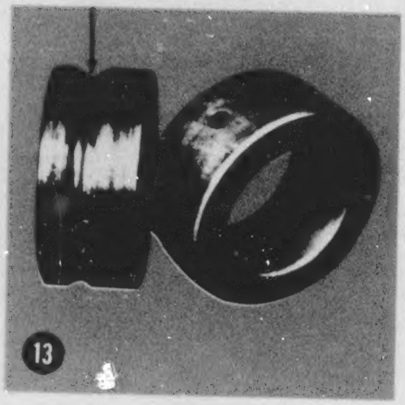


Bronze journal bearings will lose their tin plating and discolor when overheated. The plating in Fig. 11 (left) is worn and missing in spots. A new bearing is at right.

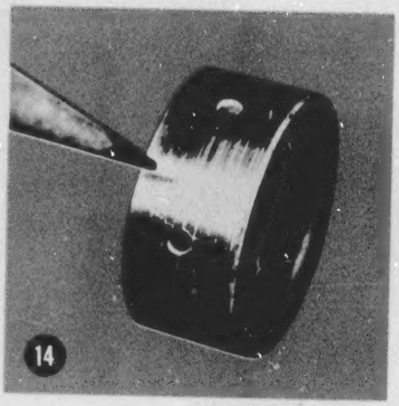


Contaminated Oil

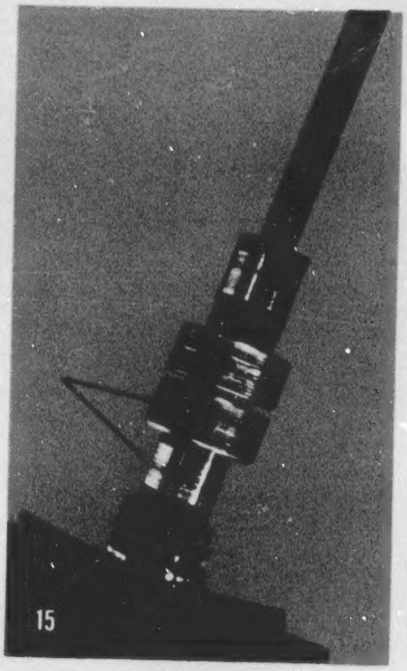
Grooves in the journal bearing may appear (Fig. 12) and heavy, deep scratches on the outer diameter of



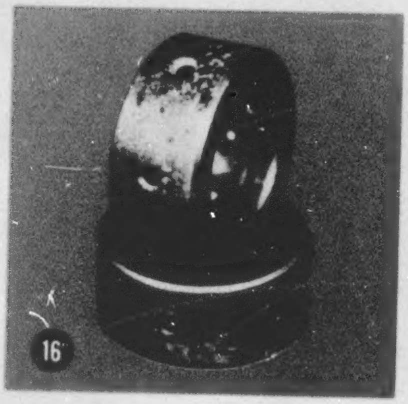
journal bearings (Fig. 13) indicate abrasive matter in the lubricating oil. The bearing on the right is normal wear.



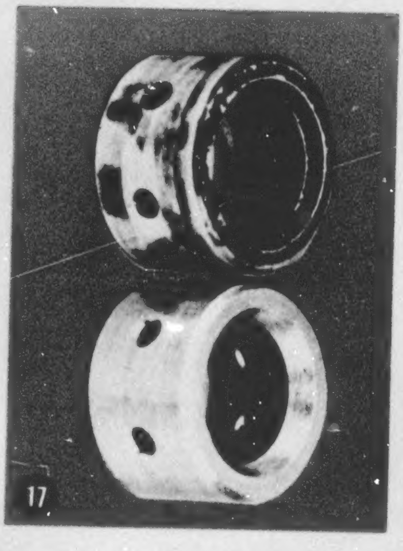
Outer bearing surface is scored and worn and the plating missing (Fig. 14) because the lubricant was contaminated.



Contaminated oil caused the bearing and shaft scoring in Fig. 15.

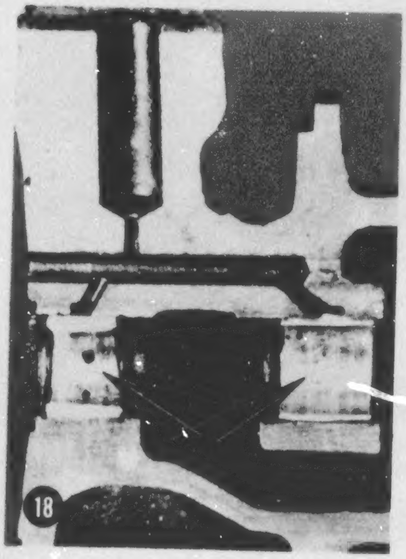


Contaminant may become imbedded in aluminum bearing surfaces (Fig. 16) and cause heavy wear on shaft journals and bearings.



Unbalanced Rotating Assembly

An unbalanced rotating assembly has a tendency to pound the bearing (Fig. 17). This will generally shrink the size of the oil passages, reducing the oil supply.

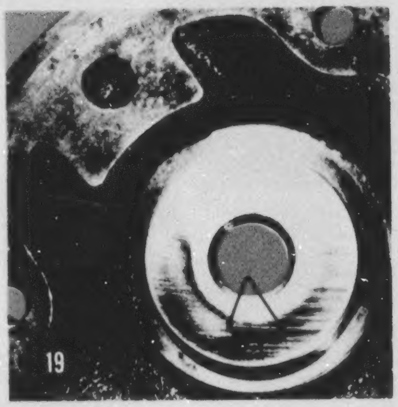


The bearing can seize in the housing bore (Fig. 18) if unbalance is not corrected. The shaft will continue to pound the bearing until the oil passages are closed.

THRUST BEARINGS

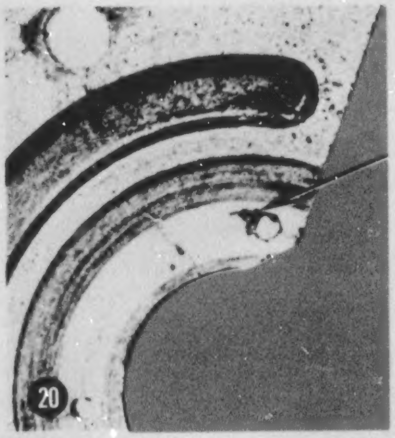
The principal causes of thrust bearing parts failures are:

- *Oil starvation (a major cause of turbocharger failure)*
- *Contaminated oil*



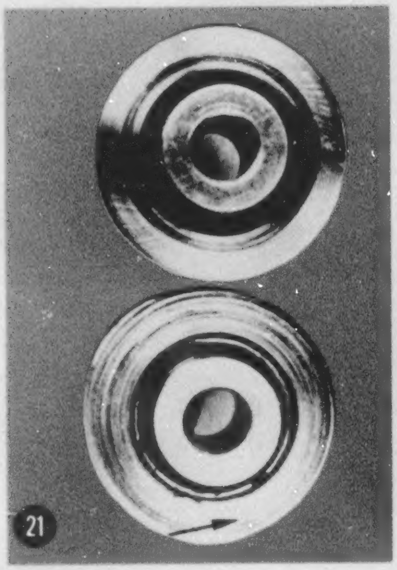
Oil Starvation

Heat discoloration of thrust rings indicates a lack of lubricant (Fig. 19). Often rubbing marks are present (arrow).

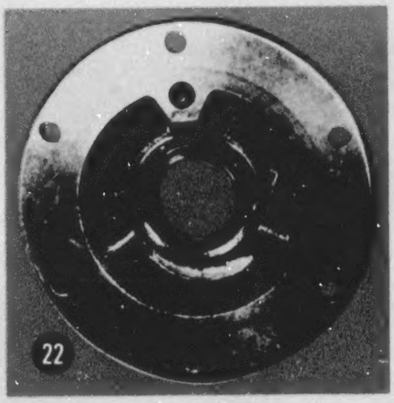


Contaminated Oil

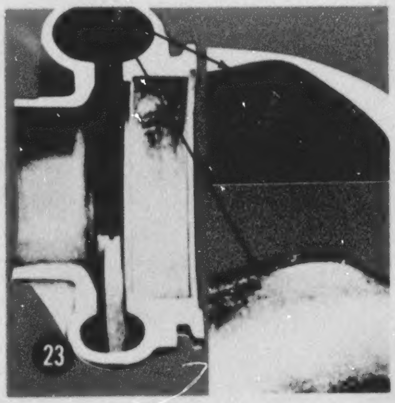
Foreign material in the oil causes erosion around the oil passages (Fig. 20).



Contaminated oil can also wear the thrust collar (Fig. 21). Excessive end play can develop.

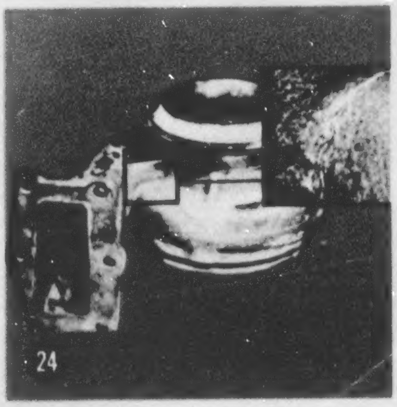


Shaft motion and bearing damage caused by lack of lubricant or foreign material can, in turn, break thrust bearing parts. Thrust washer worn and broken away is shown in Fig. 22.

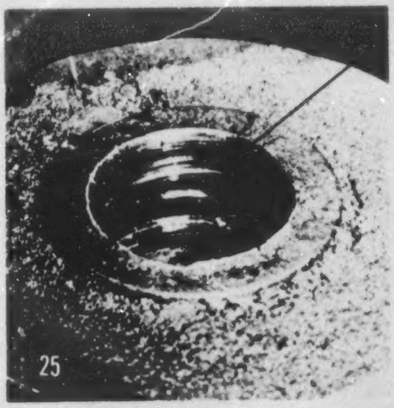


HOUSINGS

Turbine housing cracks can result from foreign material entering the housing, excess temperature, or thermal stress (Fig. 23). In some instances it appears as a slow wearing away of the housing. Eventually it terminates in rupture.



Extreme temperature cracks are identified as random hairline cracking (Fig. 24). High temperatures can be caused by exhaust and intake leaks, gross overfueling, use of the wrong turbocharger for the engine, and abuse of the turbocharger, especially at high altitude conditions.



If the seal ring area of the housing is heavily rubbed by the turbine wheel hub (Fig. 25), the cause is often shaft motion or journal bearing damage.

GEARS — Chapter 5

GEAR TERMINOLOGY

Parts of the gear that are discussed in this chapter are shown in Fig. A. These terms apply to all types of gears.

Fig. B also shows gears with some backlash or clearance between two gears in mesh. Too much backlash can result in severe impact on the gear teeth from sudden stops or reverses of the gears.

INTRODUCTION

The principal causes of gear failure are:

- **Wear**
- **Pitting, spalling, case crushing**
- **Fatigue**
- **Impact**
- **Rippling, ridging and cold flow**
- **Combined effects**

Many gear failures result from overloading a gear or from impact and shock loads brought on by improper shifting or clutching. Under normal recommended loads, most gears perform satisfactorily.

Only an examination by a metallurgical laboratory can determine if imperfections exist in a gear.

Some gears are case-hardened by heat treatment after they are machined to the final form. A hardened case (Fig. A) is produced by heat treatment providing a hard, wear resistant surface supported by a lower-hardness, tough core.

Wear

Wear is a removal of surface material from the gear. It can be slow, such as scuffing, or rapid, such as scoring. There are three types of wear;

- *Adhesive wear* – caused by metal-to-metal contact with surfaces welding together, then tearing apart. Possible causes are inadequate lubrication or the gears not properly in mesh.
- *Abrasive wear* – caused by foreign particles, such as dirt and grit.
- *Corrosive wear* – a chemical attack of the gear surface from contaminated oil or an additive.

Pits, Spalls and Case Crushing

Pits are a type of fatigue failure and appear when small particles of the gear separates from the tooth surface. As the surfaces of mating gears come in contact, the repeated stress on these surfaces can cause pitting.

They start along the line of contact where the pressure is heaviest against the teeth of the mating parts and are generally caused by excessive loads. Frequently a fatigue crack will start at a pitted area. Spalls are an advanced state of severe form of pitting and part of the gear may crack off.

Case crushing (crushing the outer, hardened surface of the gear teeth) is generally indicated by cracks running along the face of the tooth. It is usually caused by excessive operating loads.

Fatigue

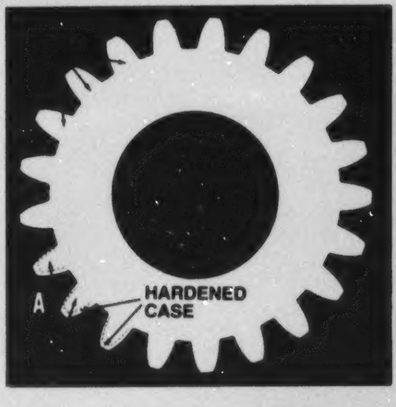
Fatigue is generally due to repeated, excessive loads that fracture gear teeth, usually at or near the tooth root.

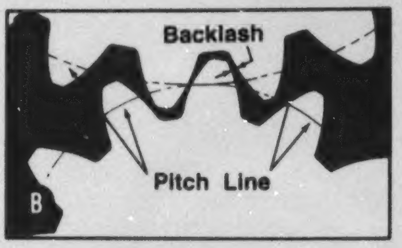
Fatigue failure may start as a small crack, caused by an extremely high load, and continue under normal operation until the gear fails. The fractured face usually consists of two zones:

- *The smooth fatigue zone, with progressive stages of crack growth*
- *The final-fracture zone which is rough (Fig. C).*

Impact

Impact failures are generally caused by severe loads resulting from abusive service. The failure usually takes place at or near the tooth root and the fractured face is gray and grainy, without evidence of progressive failure.





Rippling, Ridging, And Cold Flow (metal movement under high pressure at room temperature)

Rippling, ridging and cold flow occur less frequently and tend to be less destructive. They are surface condition exhibiting deterioration and surface flow of the material.

Some forms of surface damage are a combination of pitting and fatigue, ripples and spalling, and others.

As an approximate guide the following percentages represent a breakdown of failures based on the study of 200 gears which failed in service.*

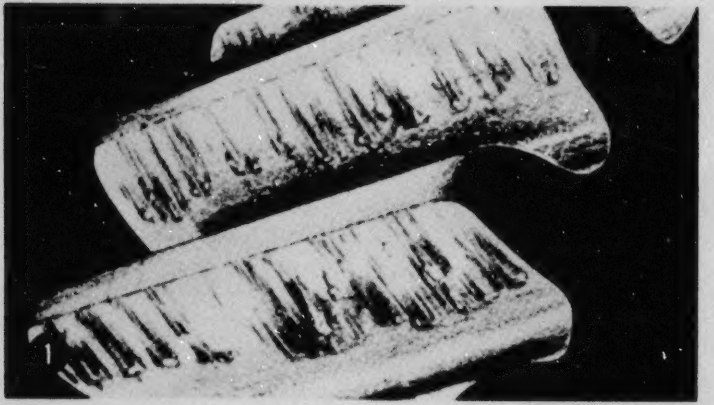
	Percentage
Fatigue	24
Impact	15
Surface Conditions: Pitting, spalling, case crushing	20
Surface Conditions: Excessive wear, scuffing, scoring, seizing	18
Foreign objects enmeshed in the gears	10
Others	13

*Why Gears Fail, Metals Review, March 1966

(The gears studied were spur, helical and bevel gears employed in heavy duty service.)

The following sections on gears identify:

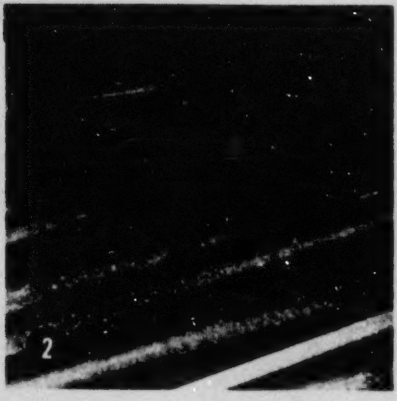
- *General category failures – common to all gears, regardless of application and assembly conditions*
- *Specific category failures – common to gears in rear axles and transmissions*



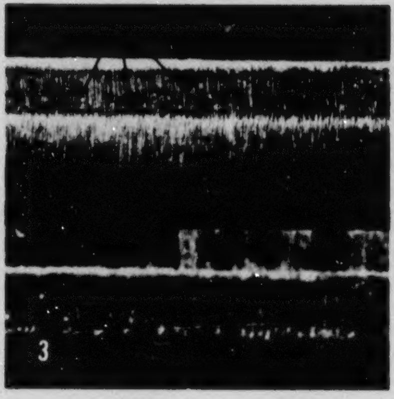
GENERAL CATEGORY OF FAILURES

Wear

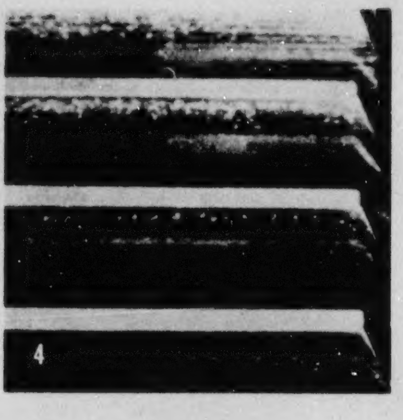
An adhesive type of wear is shown in Fig. 1. Possible causes are inadequate lubrication or gears not properly in a mesh.



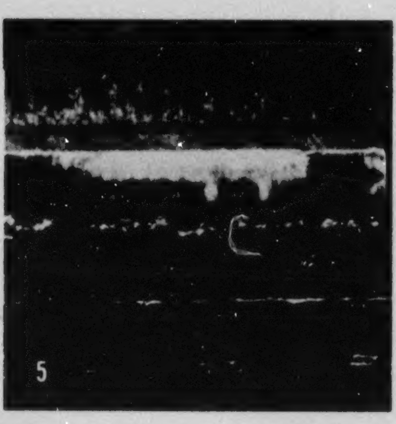
Moderate wear on the face of gear teeth in Fig. 2 causes the operating pitch line to become visible (arrow). The wear probably was caused by abrasive material in the lube oil.



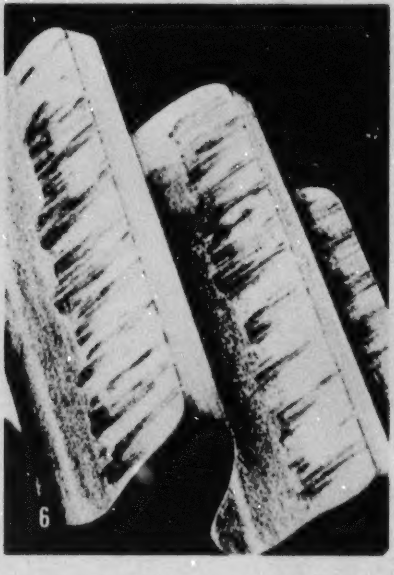
The gear in Fig. 3 suffered scoring because of metal-to-metal contact under heavy pressure, resulting from inadequate lubrication. The horizontal line on the worn surface indicates the pitch line (arrows).



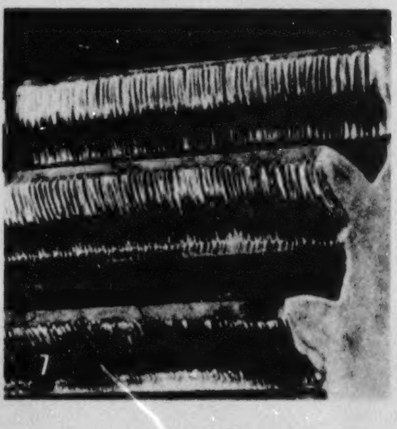
The early stages of scoring in Fig. 4 shows a spotty frosting pattern on the upper portion of the teeth. Damage is slight at this stage.



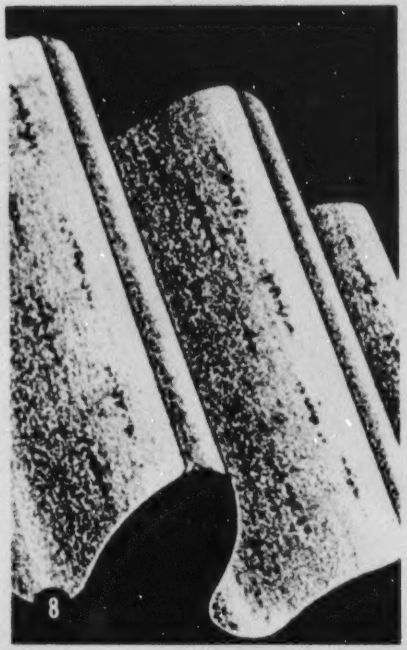
Destructive scoring is shown in Fig. 5. Heavy scoring occurred above and below the pitch line. Usually, the damage progresses quickly and the gear fails.



An abrasive type of wear is shown in Fig. 6.

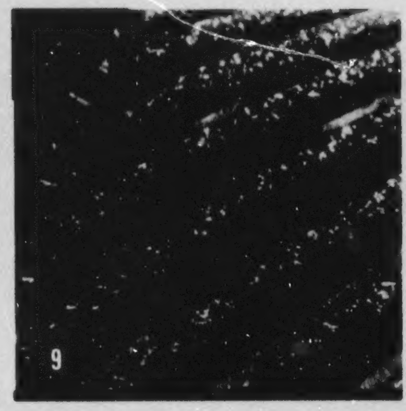


A particularly severe form is shown in Fig. 7. A large portion of the tooth of the sintered-metal or bronze pinion has worn away due to an accumulation of abrasive particles in the lubricant.



8

Corrosive wear is shown in Fig. 8. Caused by contaminants or additives in oil.



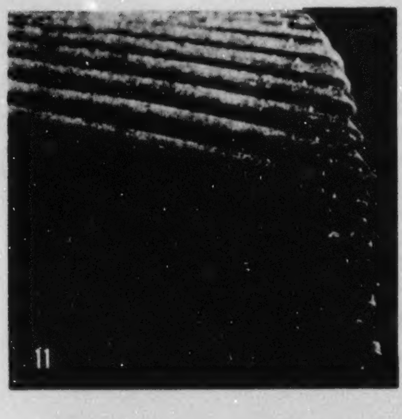
9

The gear surface in Fig. 9 was damaged by a chemical reaction. This kind of wear will continue until the gear fails. Chemical wear results from contaminated oil, composition of oil, or an additive.

10

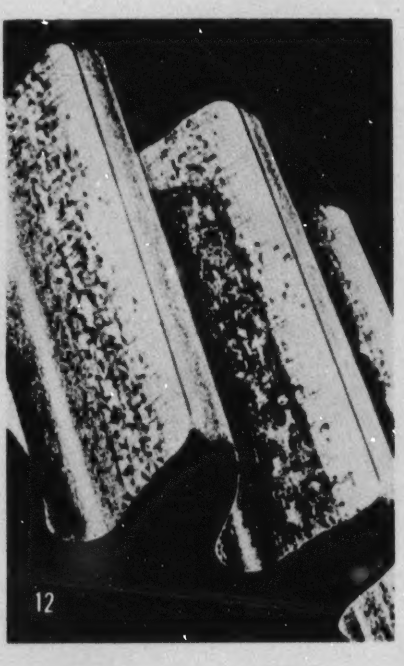
Pitting, Spalling And Case Crushing

The "corrective" pitting in the hypoid pinion in Fig. 10 consists of very small pits that do not progress beyond the initial stage, and frequently "heal over."



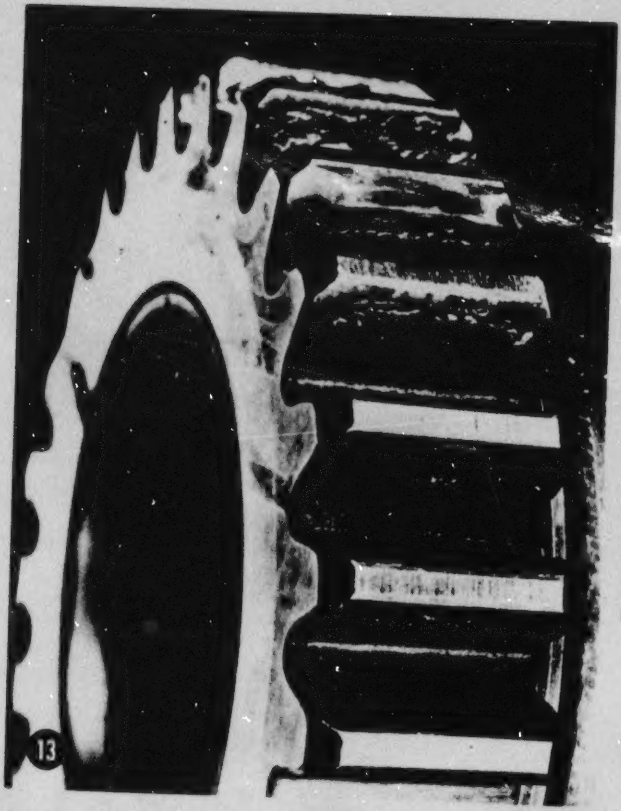
11

The pitting in Fig. 11 began on the outside end of the helix (the right edge of the gear in this picture), because of a small amount of misalignment, and worked its way to the middle of the tooth. Eventually pitting stopped and the surface began to polish, indicating that the load across the teeth became more evenly distributed. This type of pitting is not harmful.



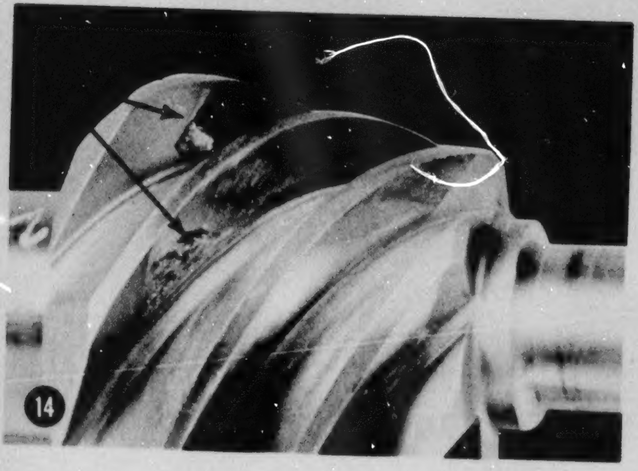
12

In contrast, destructive pitting shown in Fig. 12 probably resulted from excessive loads.



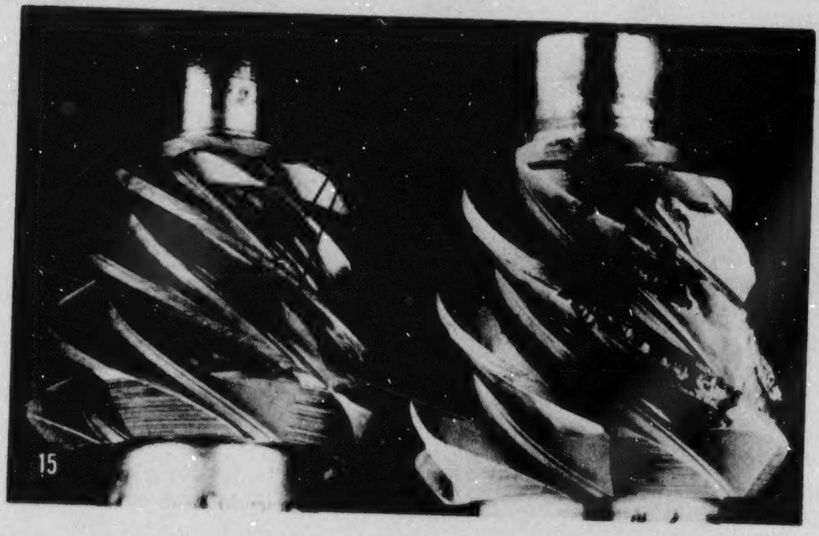
13

Pitting destroyed the surfaces of the teeth in the spur gear in Fig. 13.



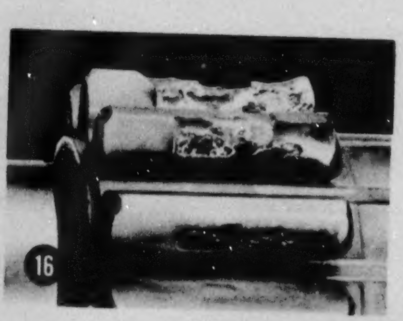
14

Pitting in Fig. 14 occurred at the heel contact. Heavy contact occurred at the location of the pits because the tooth surfaces did not mate properly, possibly because of an overload.



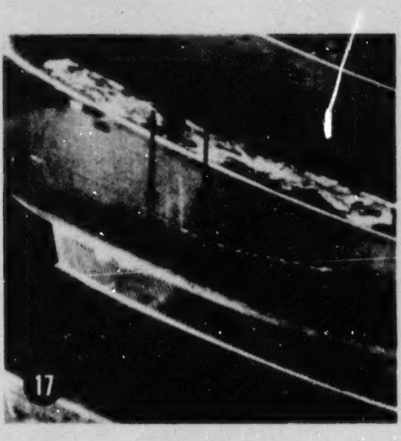
15

In the first stage of spalling, cracks running lengthwise developed on the contact area of the teeth shown at left in Fig. 15. Spalling completely destroyed the gear when the large fragments came out.

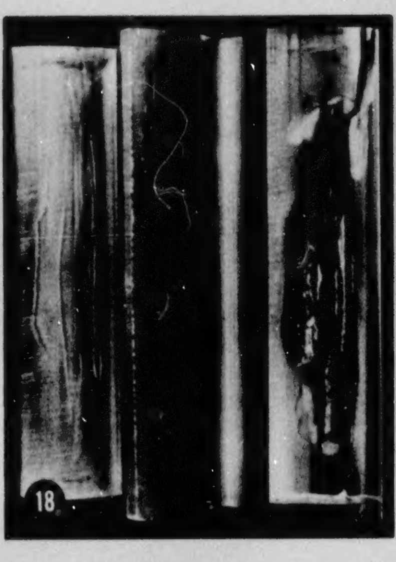


16

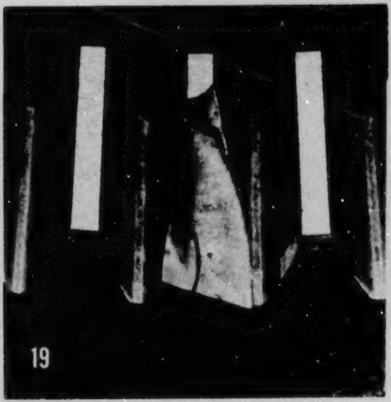
The drive pinion in Fig. 16 shows severe heavy pitting, spalling, and complete tooth destruction on successive teeth.


17

Case (hardened surface) crushing (fig. 17), is shown by lengthwise cracks in the contact surface of this bevel gear. The major cracks began deep in the case-core structure and worked their way to the surface. Long chunks of material appear about to break loose from the surface.


18

The initial appearance of case crushing of a carburized gear (a gear hardened by heating the surface, converting it to high-carbon steel, then quenching) is shown at the left side of Fig. 18 and the final stages at the right. The gear probably was overloaded but a metallurgical analysis may be necessary to determine the possible causes of failure.


19

Fatigue

A typical fatigue failure of a ring gear, with its characteristic smooth zone, is shown in Fig. 19. The failure probably resulted from a heavy load or shock load (improper shifting or clutching).

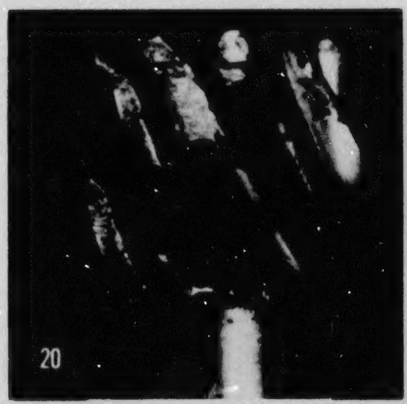
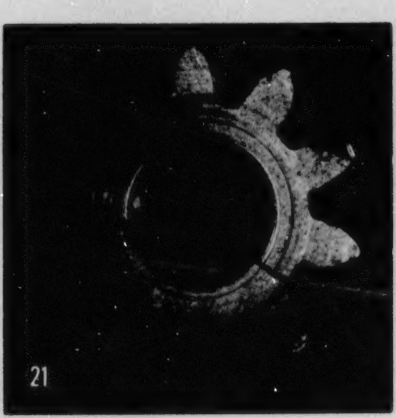
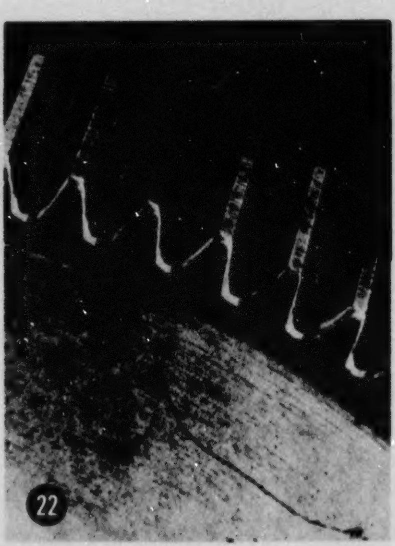

20

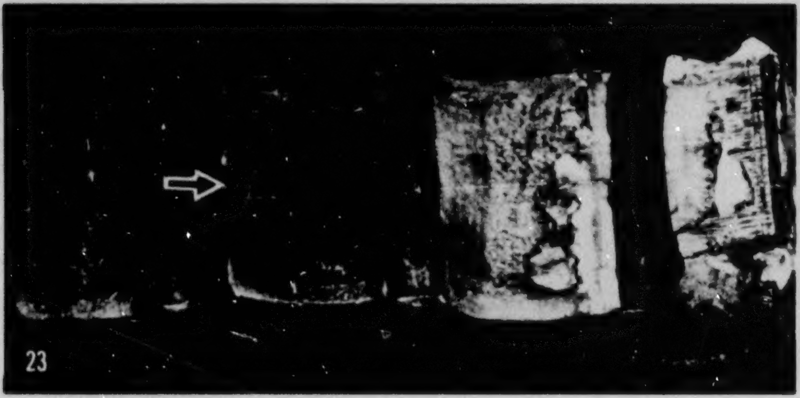
Fig. 20 shows fatigue at the root of three pinion teeth. The remaining teeth exhibited only light wear.


21

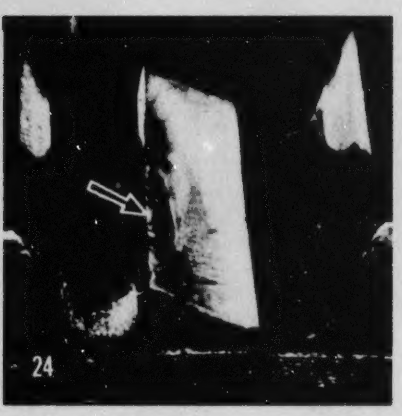
The oil pump idler gear in Fig. 21 failed from fatigue with severe tooth wear. The fracture extends from root fillets (the area connecting the bases of the teeth) to the bore in the gear. The gear should be examined by a metallurgical laboratory to determine the cause of failure.


22

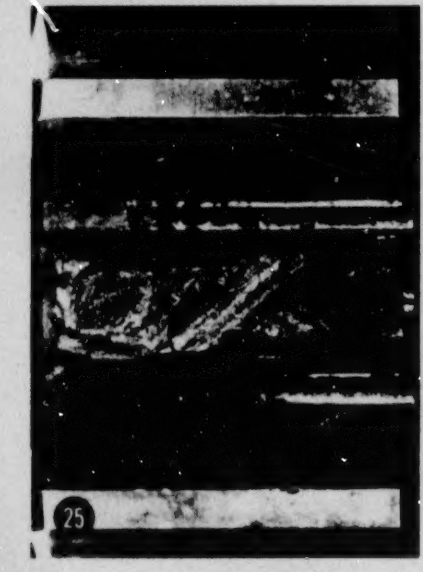
A fatigue crack extending from the roof fillet to the bore, is shown in Fig. 22. A metallurgical laboratory examination would be required to determine the possible causes of failure.


23

Fractures caused by repeated, heavy loads on several teeth of a spur gear are shown in Fig. 23. The tooth marked "A" apparently broke first (note smooth, velvety zone) as a result of a fatigue crack


24

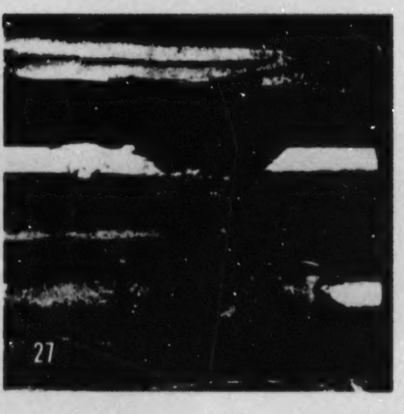
Another fatigue fracture is shown in Fig. 24. The arrow indicates the crack origin at the left edge of the fracture, where a small pit existed near the base of the contact area on the pressure side of the tooth. The area just beside the crack origin (at arrow) is well rubbed, which indicates that the crack progressed slowly at first.


25

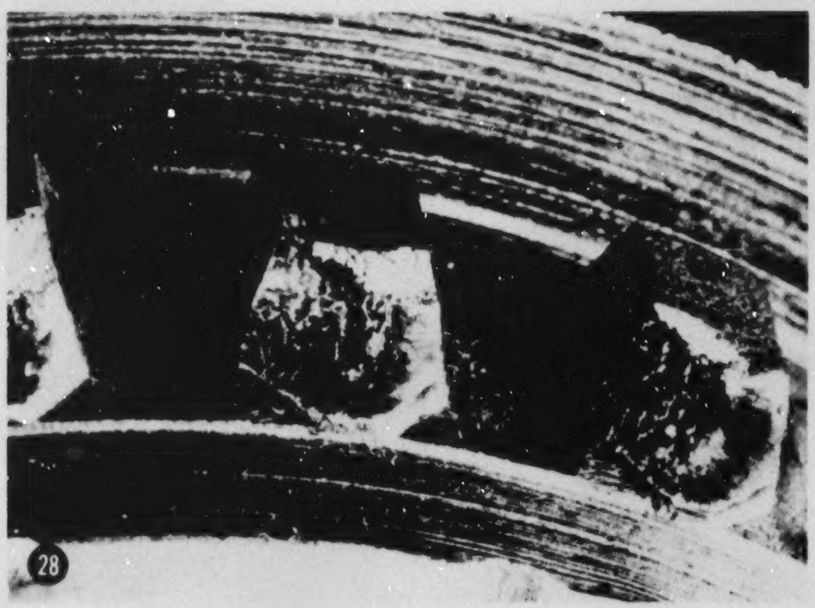
The gear failure in Fig. 25 consists of one broken tooth and cracks in the adjacent teeth. Since the fracture face was not smooth it indicates an instantaneous fatigue fracture. A pronounced band of inclusions (impurities in the gear), which act as notches promoting failure, were also observed.

26

Fatigue cracks in a case hardened gear (hardening the outside surface of the gear) in Fig. 26 began in tooth roots, forming on either side of a tooth (arrow), and meeting in the middle of the tooth. A metallurgical examination is probably required to determine the cause of failure.


27

The planet gear in Fig. 27 had most of the tips of the teeth broken off. Stresses from service loading initiated cracks at this point. Ultimately, these cracks continued, probably by fatigue, to the surfaces of the teeth. If this happens after brief service, there may have been excessive depth of the hardened surface. An examination by a metallurgical laboratory is needed to determine this.



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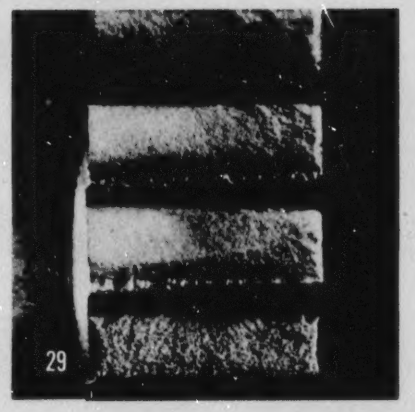


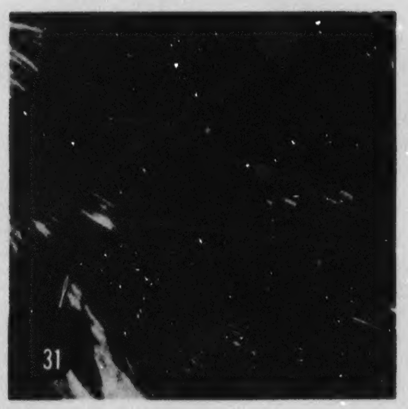
29

The break in the hardened spur gear in Fig. 29 has a gray, grainy appearance typical of a shock failure. It does not have the smooth appearance characteristic of fatigue. The failure probably resulted from improper clutching or improper shifting.

Impact

Battered and chipped tooth corners in carburized gears in Fig. 28 received repeated blows before fracturing and hid many of the fracture-surface characteristics. Improper shifting probably caused this failure.

30



31

Rippling, Ridging, And Cold Flow

Rippling, ridging, and cold flow (metal movement under high pressure at room temperature) occur less frequently than those previously described and tend to be less damaging. The surface of the gear in Fig. 30 shows waviness; a typical case of rippling on a hardened hypoid pinion. Rippling generally occurs on highly loaded gears.

The hardened gear in Fig. 31 is ridging possibly because of an overload.

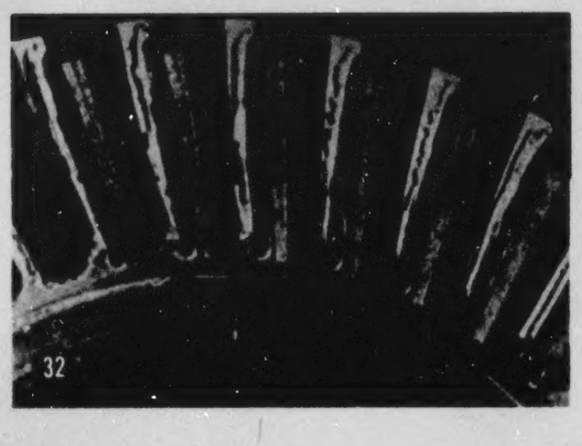
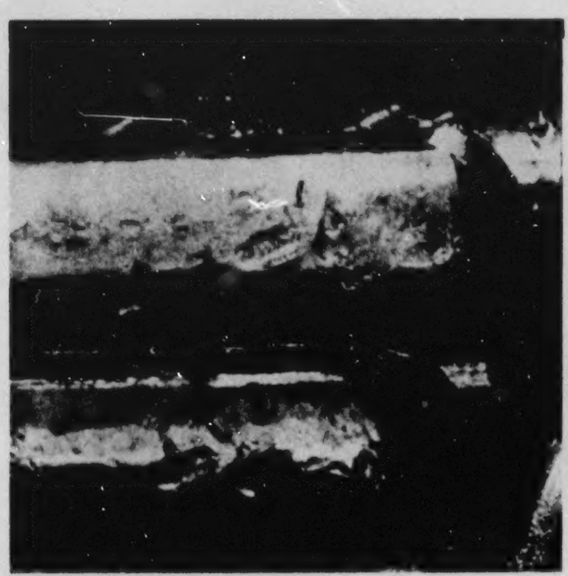


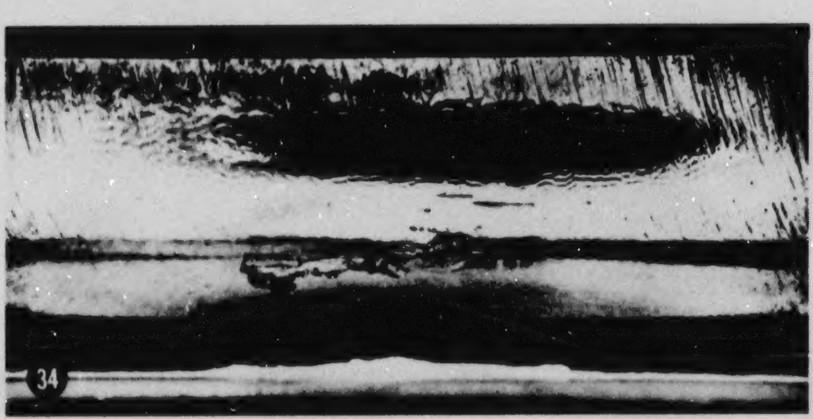
Fig. 32 shows an advanced stage of cold flow in a medium hard gear. Such gears have a greater tendency for cold flow than case hardened gears. Material has been rolled over the top edges of the gear teeth resulting in a destruction of the gear tooth profile. Heavy loads probably caused this type of metal movement.

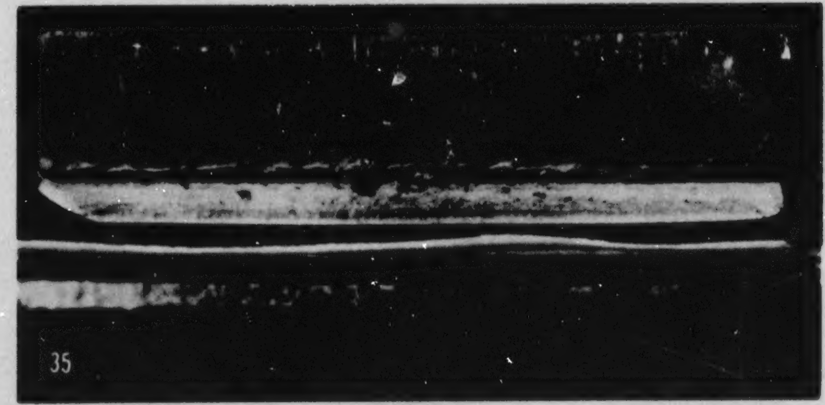


The medium hard gear in Fig. 33 shows surface deformation due to rolling and hammering action. This gear probably was overloaded and operated long after the initial damage occurred, resulting in a battered surface.

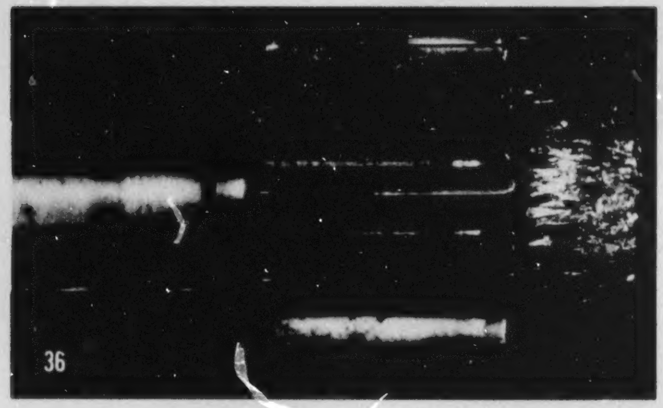
Combined Effects

Severe contact stresses caused plastic flow at the surface of the gear in Fig. 34, producing ripples. Spalling (chipping of surface material) also occurred near the tooth center. Excessive loading may be the cause of this type of failure.

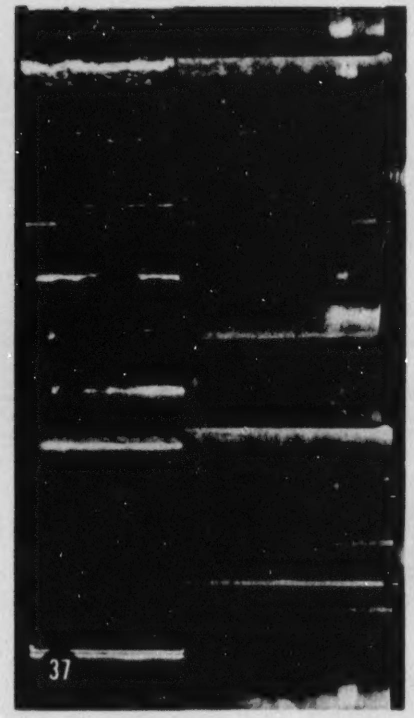


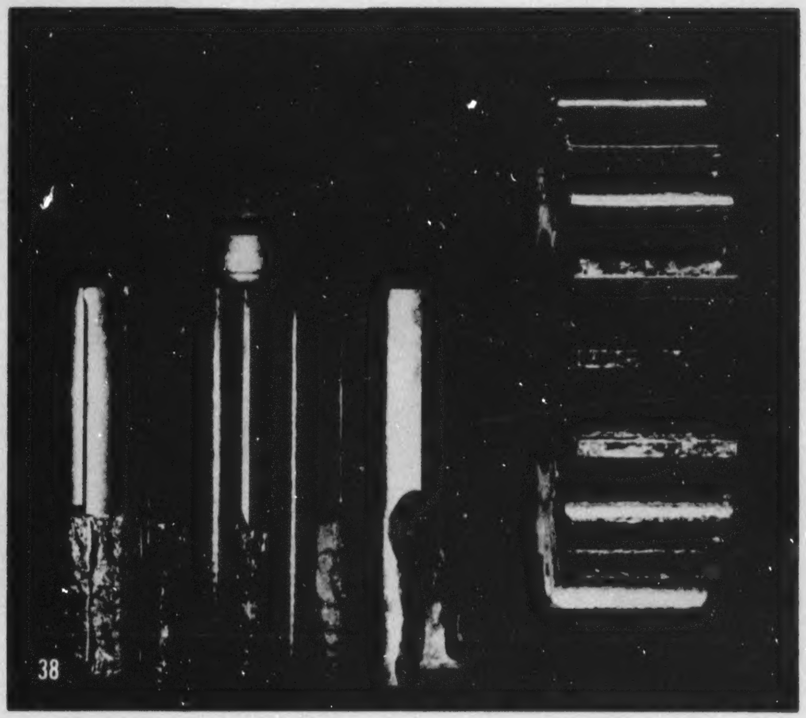


A carburized drive pinion pitted near the pitch line (Fig. 35). Also apparent are rippling along the pitch line and slight adhesive wear near the top, probably caused by overloading the gear.



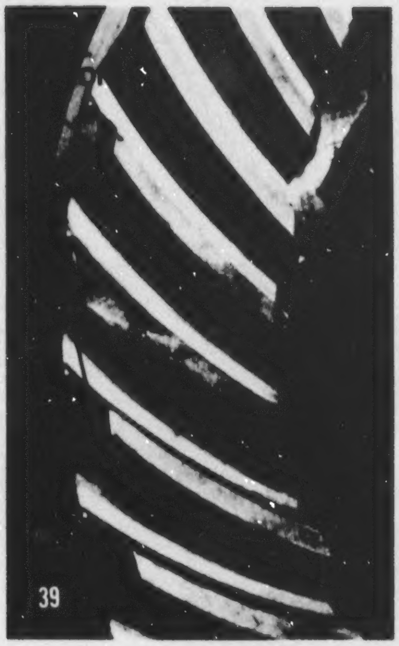
The final drive pinion in Fig. 36 failed and there was a complete destruction of the contact portion of the pinion teeth. This was probably caused by heavy loading or inadequate lubrication. The gear teeth extended to the end of the shaft before the failure occurred.





The pinions in Fig. 37 failed by advanced pitting and adhesive wear. Extreme overloading and inadequate or improper lubrication were probably the causes of these failures.

The gears in Fig. 38 shows severe battering and fatigue, probably caused by severe overloading or inadequate lubrication.

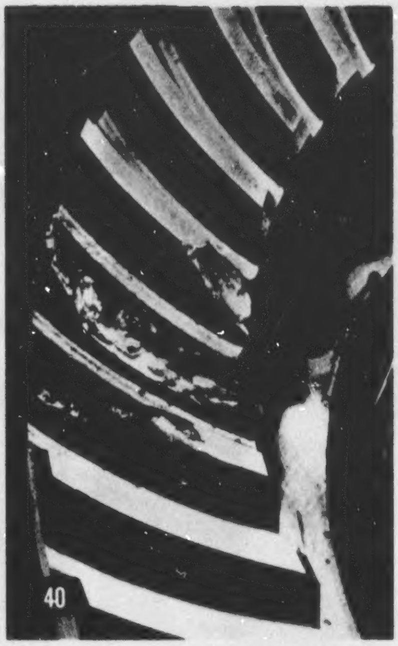


39

SPECIFIC CATEGORY OF FAILURES

RING GEAR TEETH

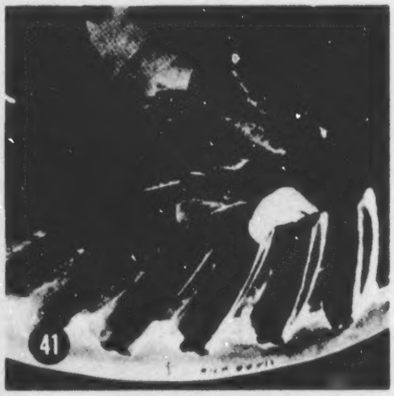
Typical examples of fractured bevel gear teeth due to improper adjustment are in Figs. 39 and 40. The failure in Fig. 39 resulted from excessive loading at the heel section of the bevel gear. The fracture in Fig. 40 resulted from excessive loading on the toe section of the gear.



40

Excessive backlash probably caused the failure in Fig. 39. While the cause of failure in Fig. 40 was insufficient backlash.

Shock loading may also cause the above conditions; even to the extent of breaking entire ring gear teeth.



41

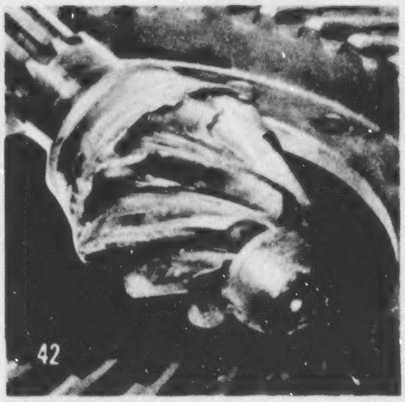
RING GEAR AND DRIVE PINION (Fig. 41)

The scuffing is spread over the tooth area. The metal had softened and was drawn across the tooth face.

Abnormal friction between gears creates heat which softens the metal and damages the teeth, if not adequately lubricated.

Worn pinion bearings permit end play by the pinion, resulting in incorrect tooth contact between pinion and ring gear.

Excessive torque could also be a cause of failure.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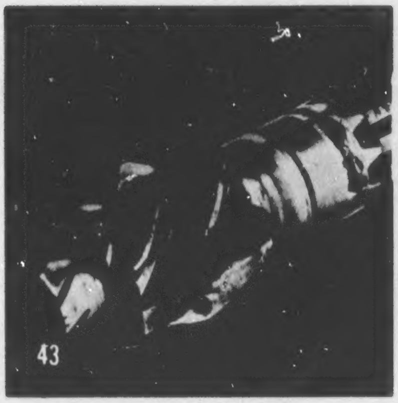
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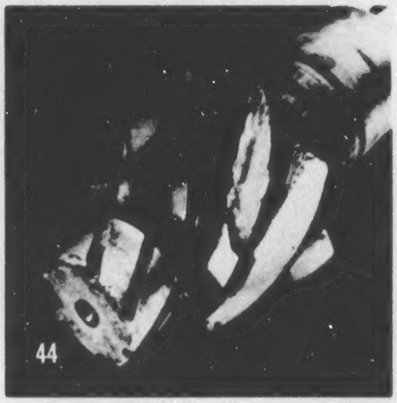

44

RING GEAR AND DRIVE PINION (Fig. 42)

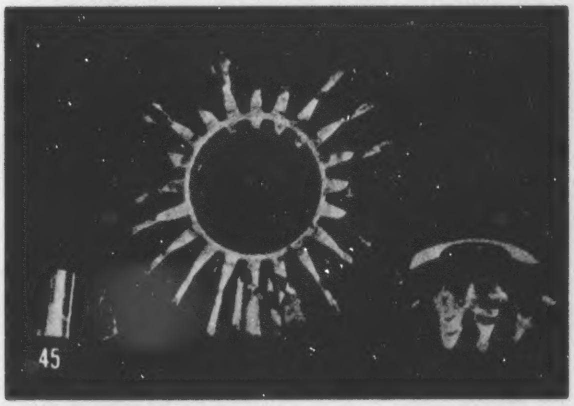
The ring teeth show discoloration and distortion. This type of failure is caused by heat generated from improper lubricant, low lubricant level, or infrequent lubricant change. In the presence of any of these conditions the surface overheats because of excessive friction.

DRIVE PINIONS Figs. 43 and 44)

Excessive loading during severe service resulted in concentration of pitted areas at tooth heel. Under excessive loading, deflection throws the pinion out of correct position in relation to ring gear and concentrates the load on the tooth heels.

The smooth zone on the face of the broken teeth in Fig. 44 is where the crack started. The rough zone indicates an area insufficient to resist a single load application.

Severe operation, defective material, and inadequate radius at the root of the tooth or poor bonding of the radius and the tooth face can cause this type of failure.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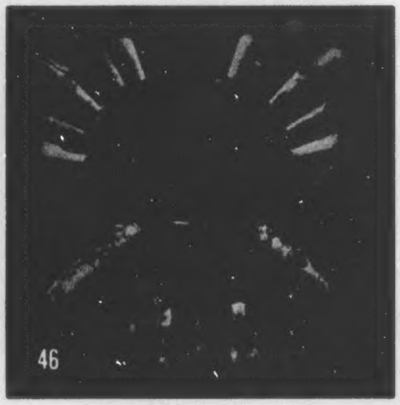

46

DIFFERENTIAL SIDE GEARS AND PINIONS (Fig. 45)

The grainy, gray appearance of the broken teeth denotes shock failure.

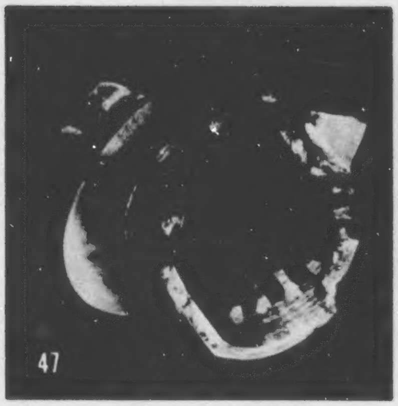
Abusive operation of the machine, such as excessive clutching, creates stresses greater than the maximum strength of the gears.

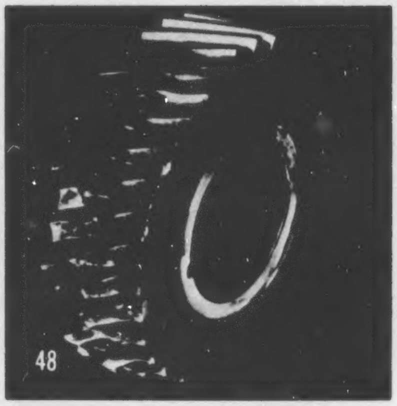
DIFFERENTIAL SPIDER ARMS AND SIDE PINIONS (Fig. 46)

Spider arms and side pinions are discolored by heat. Evidence of metal to metal contact, scoring and seizing.

This kind of damage is caused by inadequate lubrication, wheel spinning or an overload.

Any of the causes results in the loss of lubricating film between the mating surfaces. Without the oil protection, friction causes the contacting areas to overheat, score, and finally seize if running is continued.





REAR AXLE DIFFERENTIAL SIDE GEARS (Fig. 47)

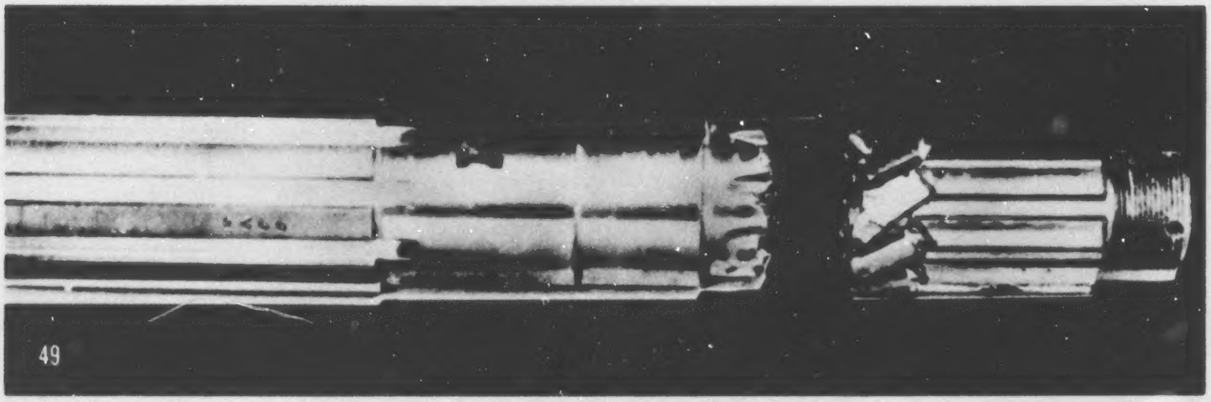
The small smooth zone of the face of fracture is where the crack started. The rough, fracture zone is the result of subsequent failure.

Abusive operation or loose wheel bearings causes a misalignment in axle shaft and housing.

TRANSMISSION HELICAL GEAR (Fig. 48)

A grainy gray appearance of the fracture, with no progressive marks is characteristic of fatigue.

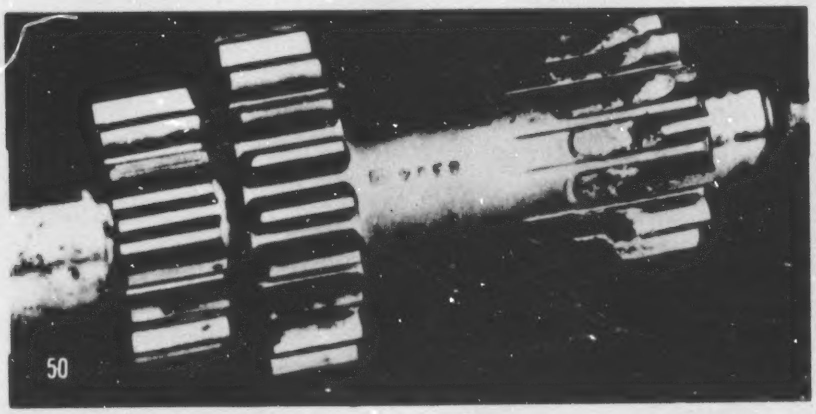
Abusive operation results in extreme shock loads. This failure is frequently associated with speeding up the engine of a load-stalled vehicle and suddenly engaging the clutch.



TRANSMISSION SPLINED MAINSHAFT (Fig. 49)

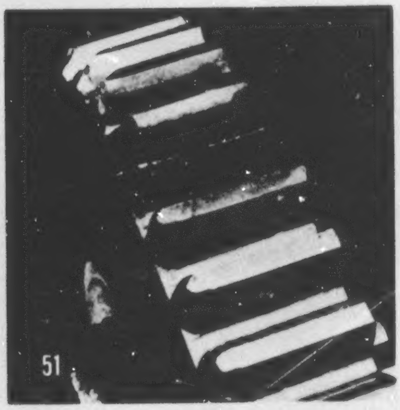
Coasting a loaded vehicle with the clutch disengaged and transmission in gear leads to this type of fatigue failure with a grainy, gray appearance. When the clutch is engaged the sudden deceleration will produce shock loads and damage various units of the drive line, in this case the mainshaft.

40



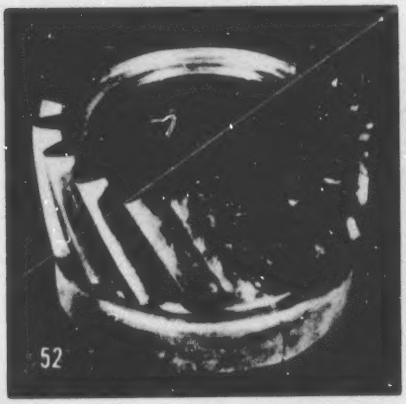
TRANSMISSION COUNTERSHAFT (Fig. 50)

Snubbed, chipped and cracked engaging teeth indicate careless shifting and failure to synchronize the speed of the two gears. Assure proper engagement and synchronization of gears.



TRANSMISSION MAINSHAFT SECOND SPEED GEAR (Fig. 51)

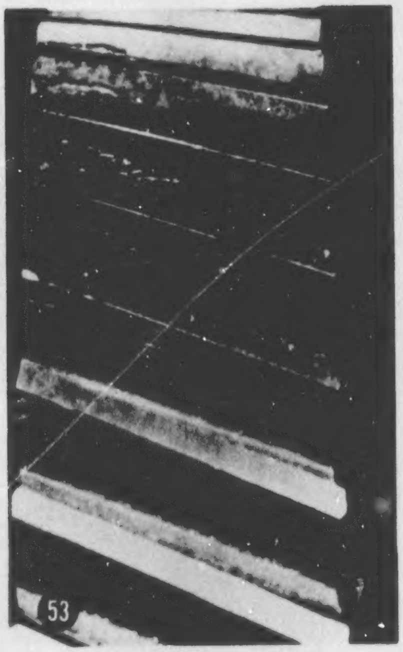
Gear teeth chipped and broken away from the engaging ends of the teeth indicate partial engagement and dragging clutch, which keeps the countershaft turning so that there is interference with gear engagement.



TRANSMISSION MAINSHAFT OVERDRIVE GEAR (Fig. 52)

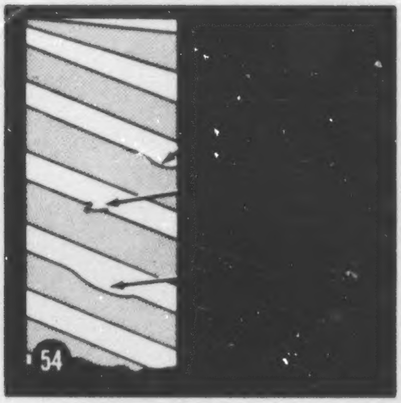
Lugging the engine under low speed and maximum torque causes extremely high pressures at the surface of loaded gears and bearings, resulting in fractured gear teeth with a grainy, gray appearance (Fig. 61), fractured output shaft and spalled bearings.

Replace the mainshaft overdrive gear and avoid lugging the engine.



TRANSMISSION COUNTERSHAFT GEAR (Fig. 53)

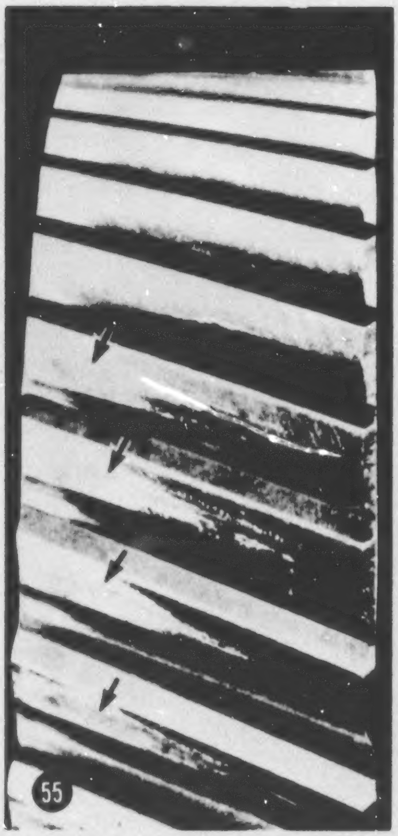
Breakdown of tooth surfaces and the concentration of pitted and spalled areas, at the edges results from excessive driveline loading during extremely severe service operation. This is associated with the housing deflection which concentrates the contact at the edge of the teeth.



54

BUMPS, BURRS AND SWELLS ON OPERATING TRANSMISSION GEAR TEETH (Fig. 54)

Bumps, burrs and swells appear on the edge of the teeth of finished gears that were carelessly handled.



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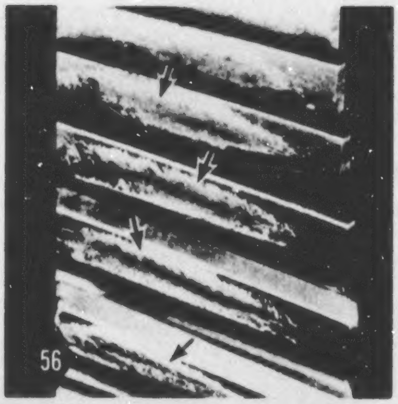

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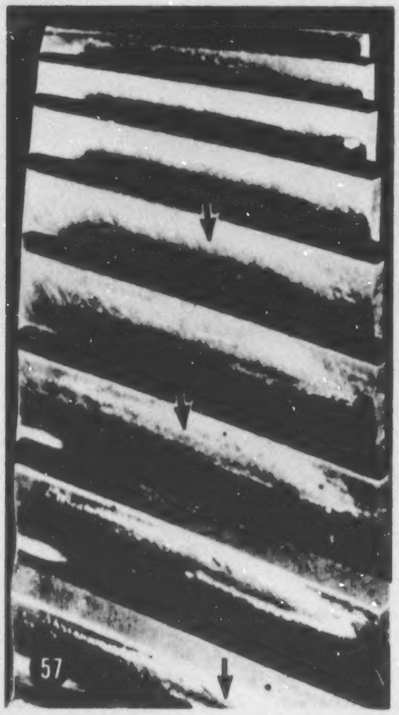


57

Appearance of Failure

Poor tooth contact illustrated in Figs. 55 and 56, contasted by a normal pattern in Fig. 57, shows up through a concentration of the polished surfaces at either end of the teeth. This results in a high pitched whine at high shaft speeds.

Excessive deflection of the gear housing or gear misalignment probably caused the failure.

These wear patterns usually do not result in failure.

SHAFTS, AXLES, SPINDLES, AND UNIVERSAL JOINTS — Chapter 6

INTRODUCTION

This section on shafts, axles and spindles is divided into two broad categories:

- **General Category of Failures**
- **Specific Category of Failures**

GENERAL CATEGORY OF FAILURES

The general category applies to failures common to all shafts, axles and spindles regardless of the application and assembly conditions. First, the following failures are described:

- **Overload failures**
- **Bending fatigue failures**
- **Torsional fatigue failures**
- **Combined fatigue failures**
- **Impact failures**

The following specific causes of failure are then described

- **Severe service**
- **Stress concentration**
- **Fretting and scoring**
- **Improper use**
- **Failure of other parts**

1

2

Overload Failure

High static loads tend to produce the type of failure shown in Fig. 1. Although the shaft has not fractured, it has twisted and is out of alignment. Static load is the weight the shaft must support while sitting still. In this case, an overload probably caused the failure.

3

Fatigue Failure

A fatigue failure shown in Fig. 2, which is more common than static or impact, has a different appearance. The first phase of fatigue takes time. As a result, the progressive portion of the fatigue fracture (A) is smoothed by the continual rubbing between the two faces of the crack. That portion which failed instantaneously (B) however, has a rough surface.

There are many variations of this basic pattern. The failure in Fig. 3 was by progressive fatigue cracking, originating at (A). The cracking progressed across most of the section before the final overload fractured the remaining metal at (B). The probable cause of failure was repeated overloading.

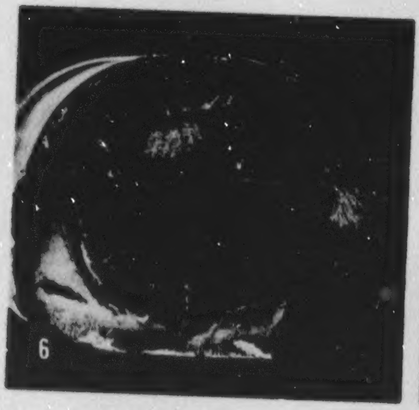
4

Torsional Fatigue

Failures in Figs. 2 and 3 were caused by twisting loads. Torsional (twisting) loads produce spiral types of failure (Fig. 4). Notice the curved line from "A" to "B".

5

Sometimes the evidence of fatigue is obscured by severe battering at the time of final fracture. The crankshaft in Fig. 5 failed initially by fatigue.



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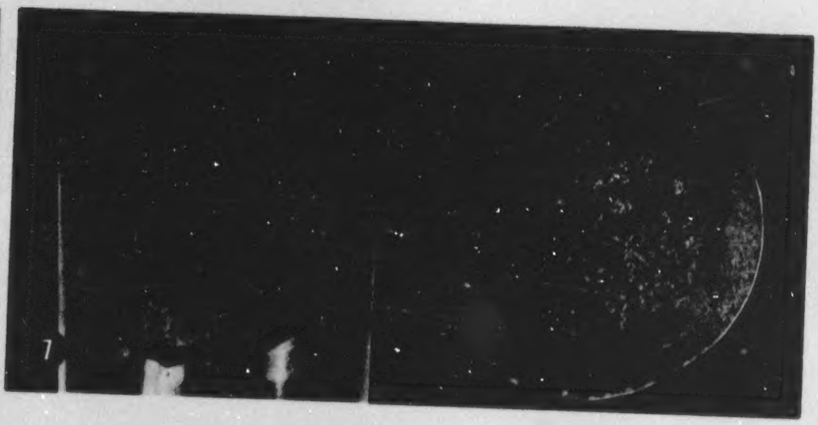


7

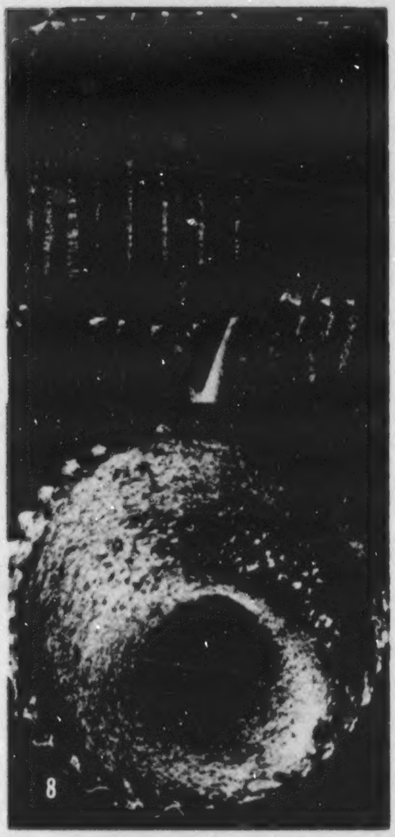
Combined Fatigue Failures

Fig. 6 shows a failure in a tractor axle due to combined bending and torsional loads.

The outer surface of the axle was hardened. The crack began in the hardened surface at the top in the photo (A). The rough area in the center (B) indicates the area of instant fracture when the axle finally broke.

Impact Failures

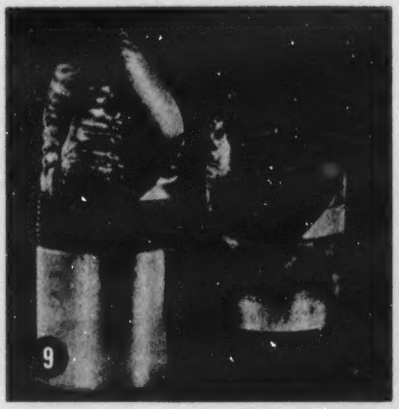
The face of a fracture caused by impact loading (Fig. 7) is usually gray, fibrous, and grainy, without evidence of progressive failure as in fatigue. The axle probably was struck by a single blow or overload causing immediate fracture.



8

Severe Service

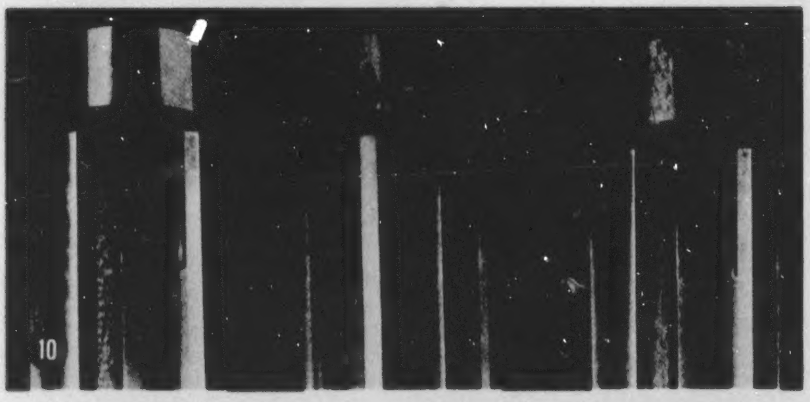
The deformation of the splines in the region of the fracture in Fig. 8 (arrows) would not occur if the fracture were caused by fatigue. The torsional, twisting during an overloaded operation caused the failure.



9

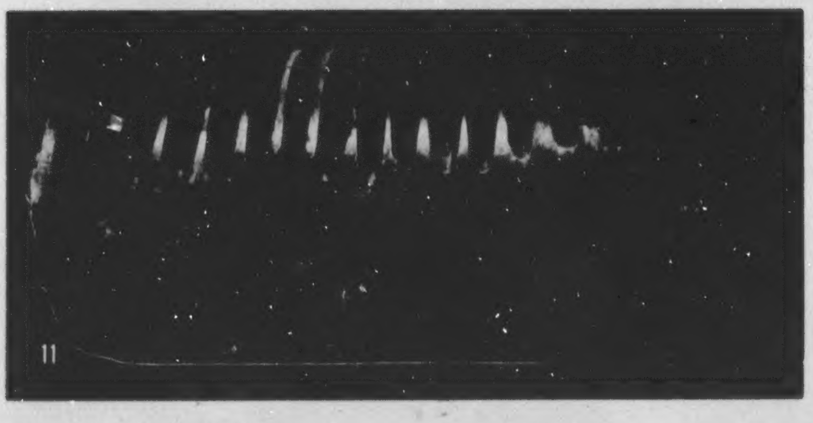
Frettage And Scoring

The failure in Fig. 9 started in at arrow due to minute rubbing action between the shaft and another part of the machine.



10

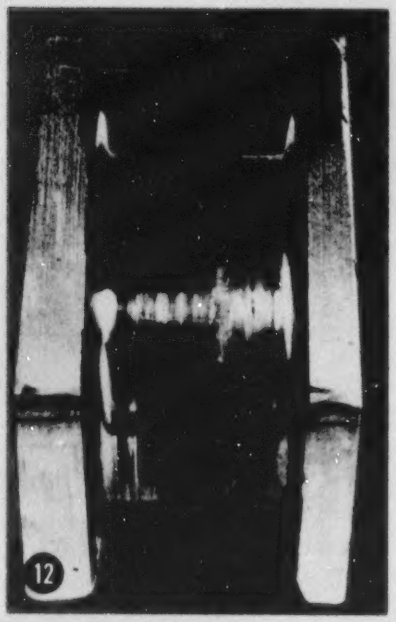
The transmission shaft in Fig. 10 shows the progressive stages of scoring. Scoring is caused by heat build-up between metal parts that rub together.



11

Improper Use

A number of irregularly shaped and spaced rack teeth were ground in beside the existing machined teeth (Fig. 11). This was definitely performed in the field.

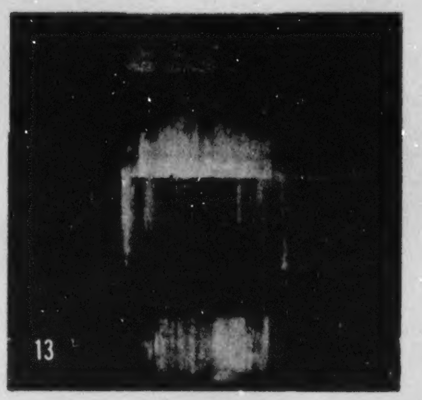


The failure in Fig. 12 is due to inadequate lubrication. The crank removed from an engine appears to be cracked. The journal surface was scratched and shows evidence of wear and exposure to high frictional temperature generated during operation. Large amounts of aluminum bearing material welded to the surface of the rod journal.

SPECIFIC CATEGORY OF FAILURES

The specific category refers to specific applications. The following specific parts are described:

- *Crankshafts*
- *Oil pump shafts*
- *Transmission shafts*
- *Wheel spindles*
- *Universal joints*

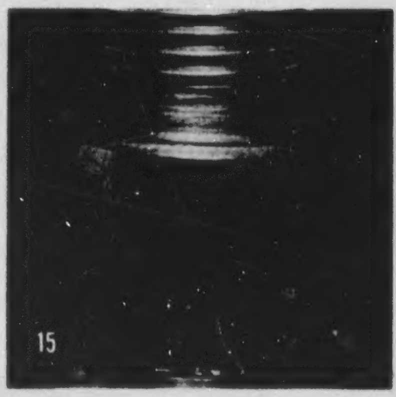


CRANKSHAFT

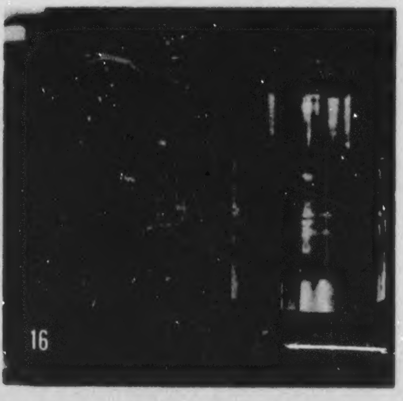
The main bearing journal of a crankshaft from a diesel engine in Fig. 13 was badly scratched by dirt particles which contaminated the lubricant.

PUMP SHAFTS

A broken pump drive shaft (Fig. 14) was overloaded from drive belts that were too tight.



The shaft of an oil pump drive gear in Fig. 15 shows evidence of fretting corrosion. Longer wear may have resulted in fatigue failure.

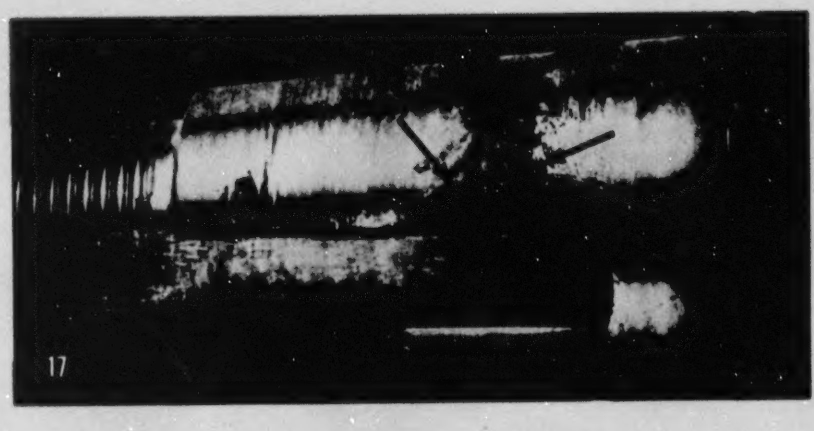


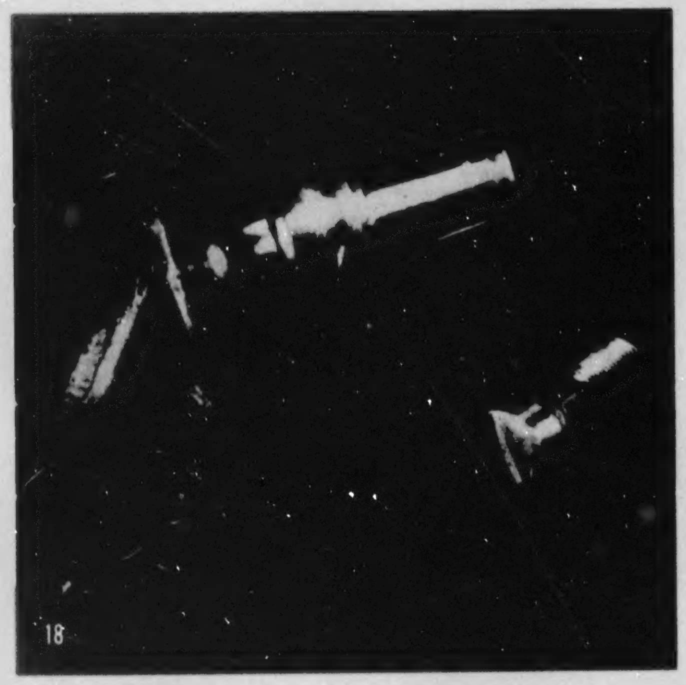
TRANSMISSION SHAFTS

The gear and shaft (Fig. 16) show galling and over-heating (discoloration on shaft beside galled area). Inadequate lubrication caused the failure.

SPINDLES

A large amount of wear is visible on both sides of the broken spindle in Fig. 17.





The fractured spindle of a steering knuckle, (Fig. 18) was caused by fatigue cracks formed at the opposite sides of the spindle at the arrow.

UNIVERSAL JOINTS

A universal joint is essentially a double-hinged joint which transmits torque at constantly changing relative angles. High loads, lack of lubrication and abrasive material are responsible for most of the damage exhibited by the universal joints.

Some recognizable signs of universal joint deterioration are:

- *Vibrations*
- *Universal joint looseness*
- *Universal joint discoloration due to excessive heat build-up*

A significant majority of universal joint failures are related to lubricating film breakdown. This may be caused by:

- *A lack of lubricant*
- *Inadequate lubricant quality for application*
- *Inadequate initial lubrication*
- *Failure to lubricate properly or often enough*

19

Failures which are not a result of lubrication film breakdown are associated with the following:

- *Installation*
- *Excessive universal joint angles*
- *Excessive operating speeds*
- *Overload*

Some common universal joint failures are described below.

Lack of Lubrication

The universal joint in Fig. 19 failed due to a lack of lubrication.

20

End Galling

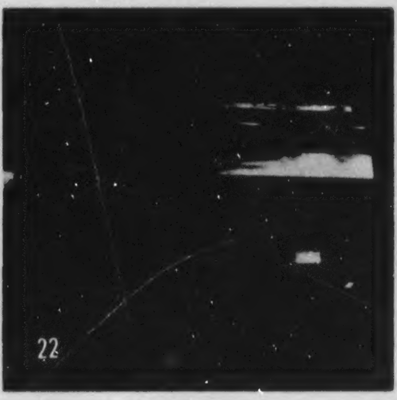
The surface damage in Fig. 20 is galling or smearing. It occurs when surfaces rub against each other, get hot, and stick together. Small pieces then tear away from that surface and are welded to another surface area.

End galling results from inadequate lubrication, inadequate clearances, and operating at sharp angles and high speeds.

21

Brinelling

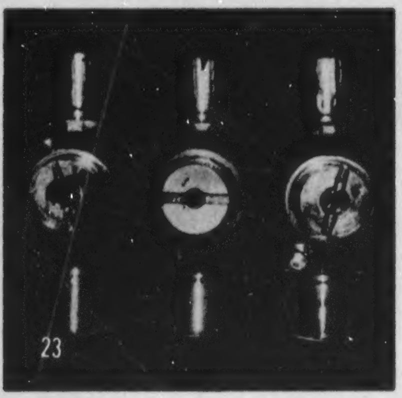
Brinelling of the universal joint in Fig. 21 is caused by another piece of metal being pressed into the damaged area shown. The fit of the parts was too tight in this figure.


22

Slip Spline Galling

Sliding splines require a uniform and complete initial lubrication around and along the length of the spline.

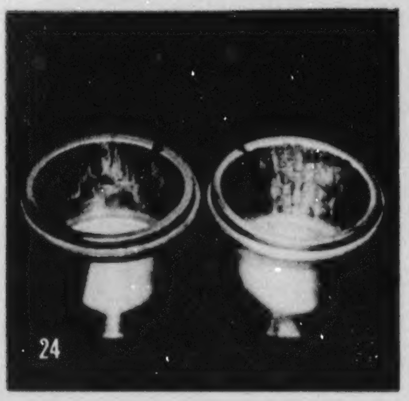
Spline surfaces can run dry if not properly lubricated. This causes localized galling (surface damage of rubbing parts being welded together from friction (Fig. 22) and burning that leads to early failure.

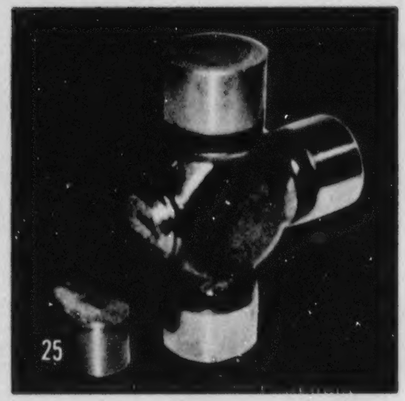

23

Fatigue

Three stages of journal fatigue failure are shown in Fig. 23 — early stages at left to severe spalling at right.

Fatigue failures result from applying too high a load for a given joint size and operating at too great an angle. Inadequate lubrication also contributes to early fatigue failure.





Fatigue failures also show up on the inside diameter of a u-joint bearing cup. (Fig. 24).

Broken Journal

Journal fracture normally occurs at the base of the trunnion — the point of highest bending stress (Fig. 25).

Excessive torques for given u-joint sizes and excessive shock loads cause this type of failure. Sudden drive shaft lock-up (as occurs during some equipment failure) causing excessive u-joint loads, high operating angles causing vibrations, and high torque fluctuations also lead to broken journals.

HYDROSTATIC TRANSMISSIONS — Chapter 7

INTRODUCTION

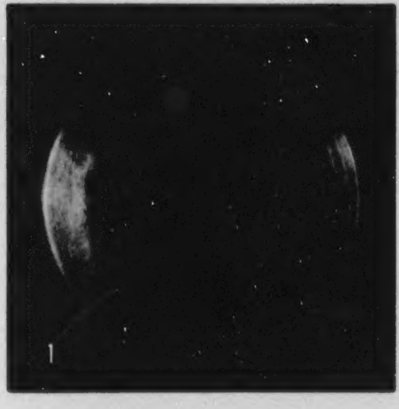
This chapter deals with failures involving the following hydrostatic transmission components:

- **Thrust Plates or Fixed Swashplate**
- **Piston/Slipper Assembly**
- **Slipper Retainer**
- **Ball Guides**
- **Cylinder Block**
- **Bearing Plates**
- **Bi-Metal Bearing Plates**
- **Valve Plates**
- **Shaft Seal**
- **Charge Pump Assembly**
- **Displacement Control Valve**
- **Servo Sleeve and Piston**
- **Shafts**

Most failures shown are for heavy-duty hydrostatic systems. Failure appearances in light-duty systems are similar to those of heavy-duty systems. See Figs. 44 through 46 for specific reference to failures in light-duty hydrostatic systems.

HEAVY DUTY HYDROSTATIC SYSTEMS

IMPORTANT: Hydrostatic systems require proper quantities and types of lubricant. These systems are very sensitive and parts fail if not properly lubricated.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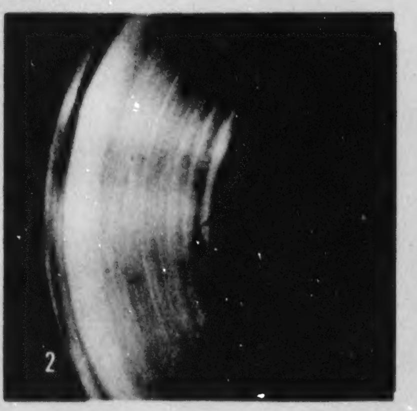

2

THRUST PLATES OR FIXED SWASHPLATES

Smearing or galling

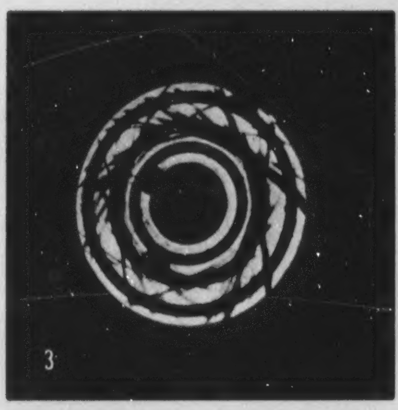
This condition is usually caused by a lack of lubrication; insufficient or improper fluid being used. Bronze material embedded into the thrust plate (metal transfer) indicates smearing or galling (Fig. 1).

Scoring

The plate in Fig. 2 was scored by abrasive contaminants suspended in the hydraulic fluid.

Scoring is indicated by fine scratches or grooves in thrust plate.

When these scratches can be detected by feel, fingernail or lead pencil, the plate should be replaced.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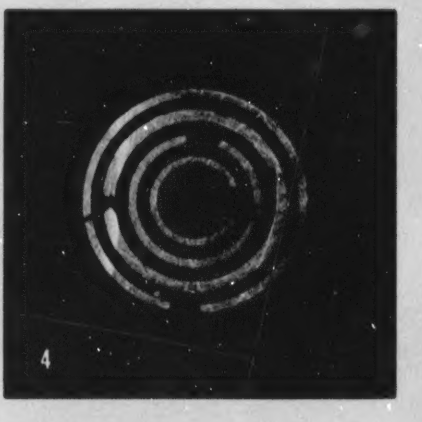

4

PISTON/SLIPPER ASSEMBLY

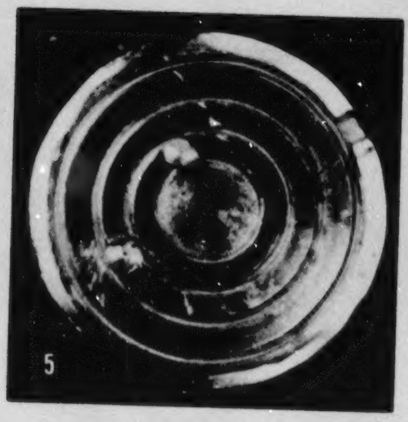
Scoring

Fine scratches across the slipper face (Fig. 3) are caused by abrasive contaminants suspended in the hydraulic fluid. There is also some discoloration which usually indicates improper fluid, or large quantities of water in the fluid.

If scratches can be detected by feel with fingernail or lead pencil, the part should be replaced.

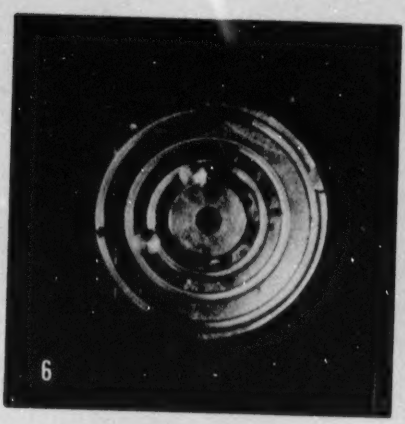
Damaged Slipper

The damage across the balance land in Fig. 4 usually begins as a deep scratch and erodes larger as high pressure escapes across this area. The original scratch is caused by a large particle of contamination.


5

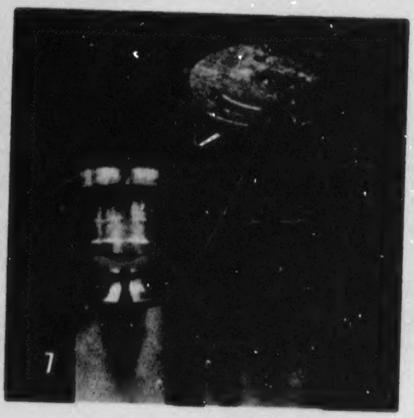
Rolled

Overspeed indicated the outer edge of the piston slipper being rolled over and in some cases the sides of the slippers being skinned up (Fig. 5). This is usually caused by the unit overspeeding which causes the slipper to ride on its outer edge rather than across its entire face.


6

Contaminated Slipper

A solid particle of contamination is embedded in the slipper face in Fig. 6 and will score the thrust plate.


7

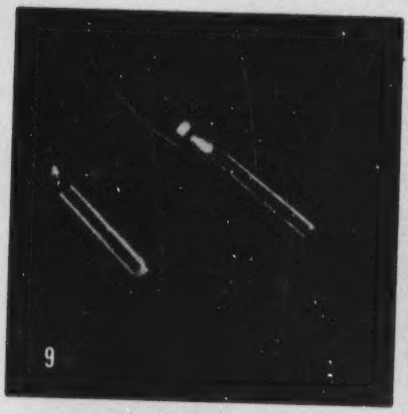
Smearing or galling

The entire face of the slipper in Fig. 7 is damaged and is caused by lack of lubrication, indicating insufficient or improper fluid in the system.

8

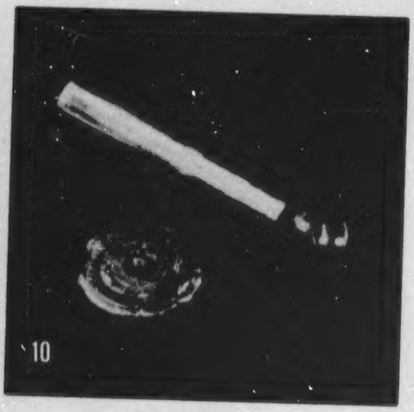
Discoloration

The discoloration on the piston outside diameter in Fig. 8 indicates the unit was subject to excessive temperature. See index, p. 10, for color illustration.


9

Piston filler separation

Separation (Fig. 9) usually results from the system being exposed, for long periods of time, to cavitation or high temperature. Cavitation occurs when excessive amounts of air or foam are present in the fluid and the air replaces the hydraulic fluid films. The air does not provide adequate support for the running surfaces. The piston filler may separate in smaller pieces or in one piece as shown. The filler insert is not replaceable.


10

Slipper separation

A stuck piston can cause a slipper to separate from the piston (Fig. 10). Excessive overspeed, contamination or lack of lubrication can cause this.

11

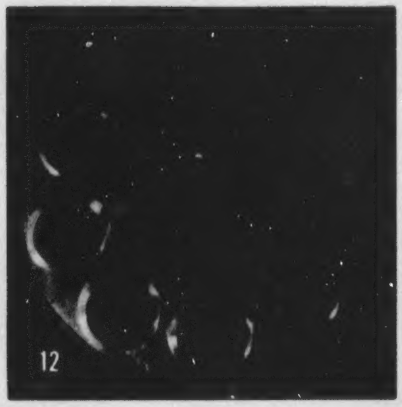
SLIPPER RETAINER

Discoloration

Discoloration on the slipper retainer in Fig. 11 indicates the retainer was subject to excessive temperature.

Excessive temperature may cause the retainer to distort or fracture.

See index, p. 10, for color illustration.



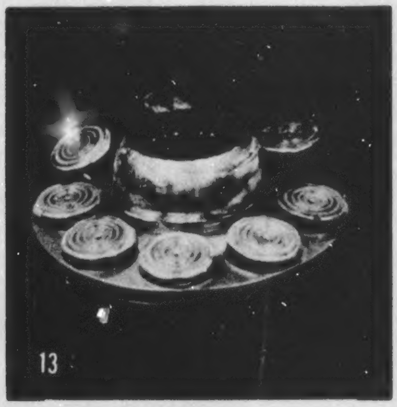
12

Scoring

A severe wearing pattern (scoring) where the piston slipper contacts the retainer is shown in Fig. 12.

This usually indicates the system was exposed to abrasive contaminants suspended in the hydraulic fluid. This same scoring may also be found on the inside diameter of the retainer where contacting the ball guide.

If this scoring can be detected by feel with fingernail or lead pencil, the part should be replaced.



13

Low system charge pressure

The slipper retainer in Fig. 13 was pulled down over the ball guide because the pressure difference between the unit case and the system charge pressure was too low.

Possible causes are high case pressure (restricted outlet), a plugged charge pump inlet filter, low reservoir level, or low speed-high pressure operation of the pump. In low speed-high pressure operations the charge pump cannot keep up with the flow demand from the pump, and charge pressure drops.

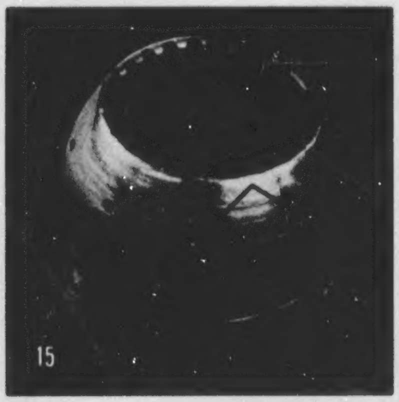
14

BALL GUIDES

Scoring

The scoring in Fig. 33 indicates abrasive contaminants between the two mating seal parts. This contamination may have been introduced from outside the unit or could have been suspended in the hydraulic fluid.

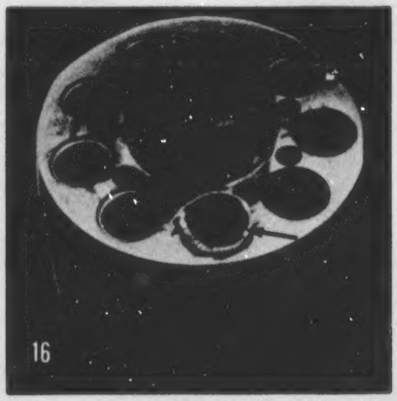
When these scratches can be detected by feel, fingernail, or lead pencil the ball guide should be replaced.



15

Worn

The worn areas around the lubrication holes (Fig. 15) usually indicate a lack of lubrication or abrasive contaminants in the hydraulic fluid.



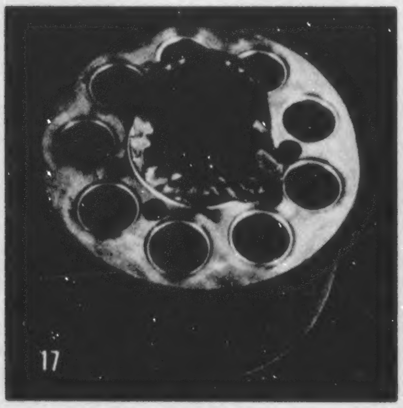
16

CYLINDER BLOCK

Pulled Bushing

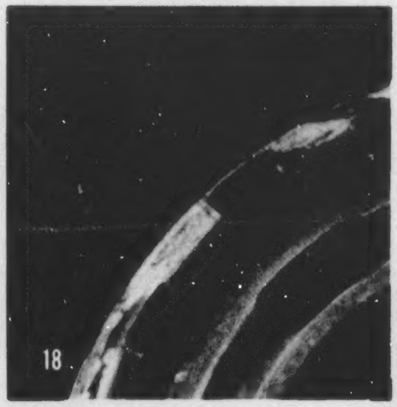
The pulled bushing in Fig. 16 may have been caused by a seizure of the piston in the cylinder bore as a result of contamination, overspeed, or lack of lubrication.

The cylinder bore bushings are not replaceable.


17

Fracture

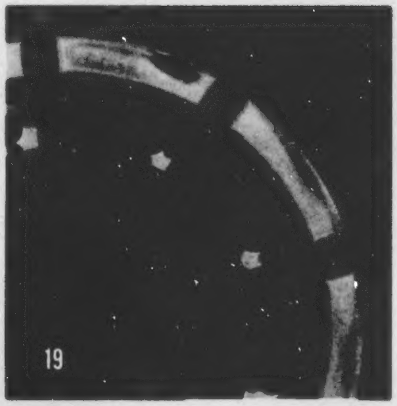
Excessive system pressures or excessive misalignment could have caused the fracture in Fig. 17.


18

BEARING PLATES

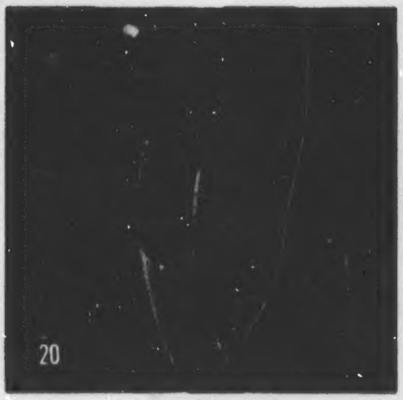
Smeared-outer edge

The bearing plate in Fig. 18 shows smearing on the outer support area. Smearing is a metal transfer caused by severe friction between rotating parts.


19

Erosion

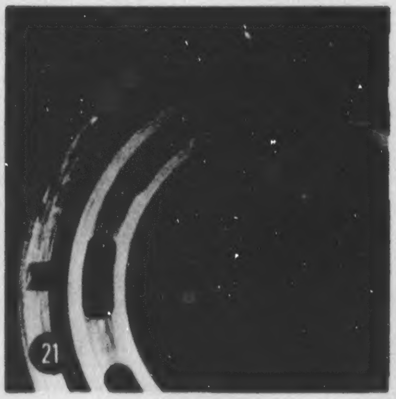
The cylinder block side of the bearing plate may show erosion on the balance land in Fig. 19 resulting in excessive internal leakage.


20

Grooved

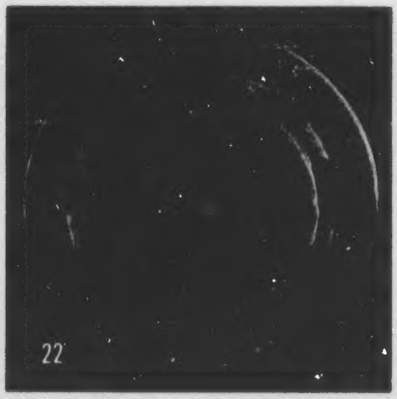
Grooves between the kidney (Fig. 20) are usually caused by abrasive contamination in the high pressure circuit.

If the groove can be detected by feel with fingernail or lead pencil, the part should be replaced.


21

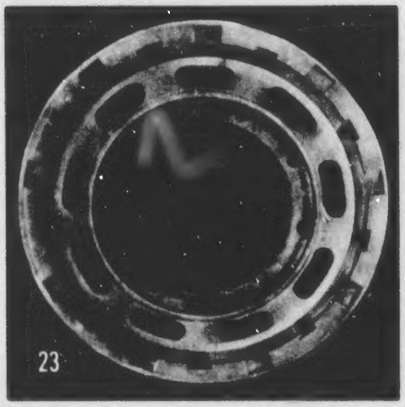
Total smearing

The bearing plate in Fig. 21 shows smearing across its entire surface, usually caused by abrasive contamination or by lack of lubrication.


22

Discoloration and smearing

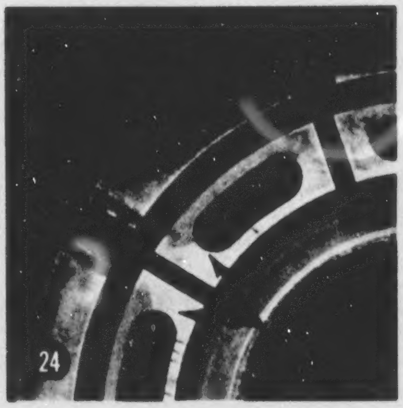
The plate in Fig. 22 is starting to score because of lack of lubrication or improper fluid. The color appearance also indicates improper fluid or a chemical reaction to the bearing plate material. See index, p. 10, for color illustration.



Discoloration

A bearing plate too dark in color (tarnished) (Fig. 23) usually indicates improper fluid or large quantities of water suspended in the fluid. Excess temperature may also cause discoloration.

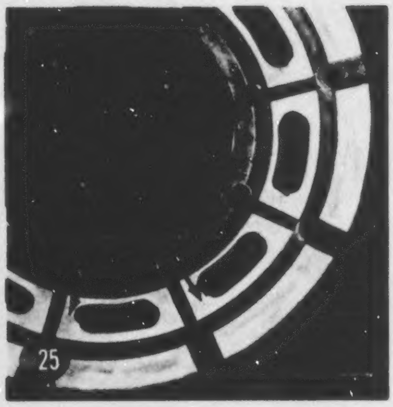
See index, p. 10, for color illustration.



The lighter area on the cylinder block side of the plate in Fig. 24 shows wear caused by plate movement against the cylinder block.

Excessive temperature and improper fluid may cause the plate to flutter causing a wear pattern on the cylinder block side of the plate.

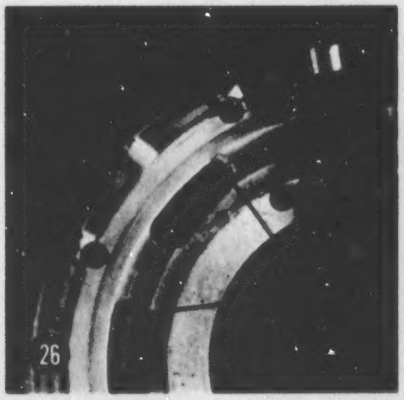
See index, p. 10, for color illustration.



Cavitation

Cavitation erodes the kidney area of the bearing plate on the cylinder block side (Fig. 25).

When cavitation occurs on the inner or outer balance lands the plate should be replaced.

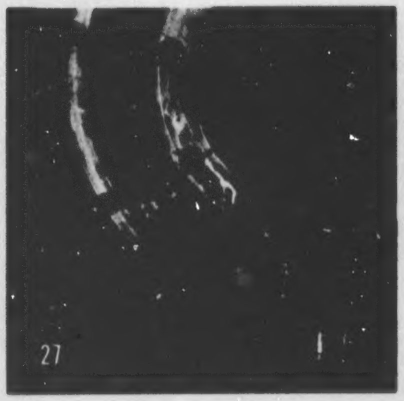


BI-METAL BEARING PLATES

Bi-metal bearing plates are made of bronze bonded to steel and have a different color. In general, the previously described guidelines also apply to the bi-metal plates.

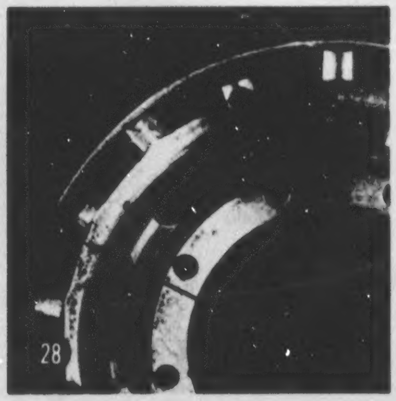
Total Smearing

The bearing plate in Fig. 26 shows slight erosion due to cavitation in the kidney areas with smearing across the entire running surface. The probable cause is lack of lubrication.



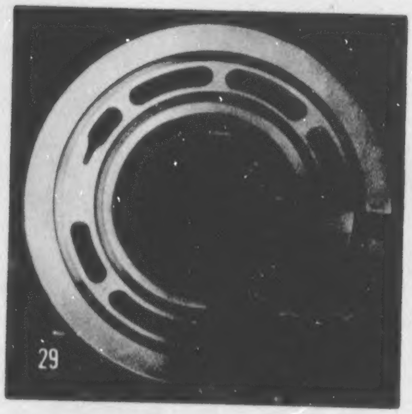
Cavitation

The advanced stages of cavitation in Fig. 27 shows some bronze material eroded completely away from the steel base material of the plate at the kidney areas. This condition usually is caused by air bubbles trapped in the fluid.



Metal separation

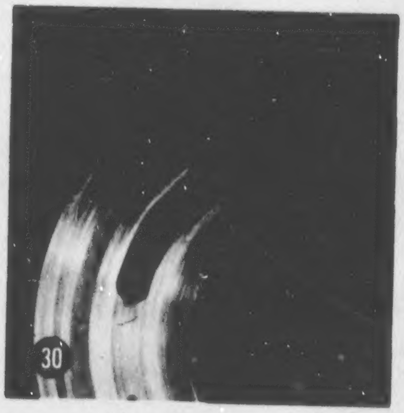
Bronze material removed from the bearing plate in Fig. 28 indicates extended cavitation in the system. High temperature may also contribute to metal separation from bi-metal plates.



VALVE PLATE

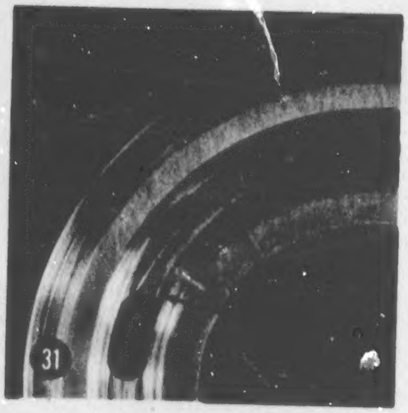
Contamination

A particle of contamination embedded on the back side of the valve plate in Fig. 29 can cause the plate to lift and result in excessive internal leakage and damage the bearing plate.



Smearing

Smearing is normally caused by a lack of lubrication, insufficient or improper fluid, or excessive temperature (Fig. 30).



Grooving

The grooves and nicks between the kidneys and smearing on the bearing areas indicate abrasive contaminants are suspended in the hydraulic fluid (Fig. 31).

SHAFT SEAL

Grooving

The severe groove in the bronze rotating part of the seal in Fig. 32 indicates the seal was subject to abrasive contamination.

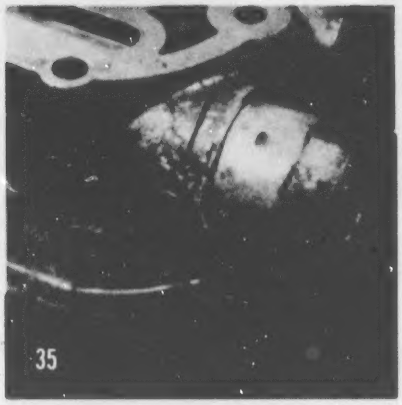
Excessive outside pressure against the mating seal parts, possibly caused by nonvented gear box can cause this type of failure.

Scoring

The scoring in Fig. 33 indicates abrasive contaminants between the two mating seal parts. This contamination may have been introduced from outside the unit or could have been suspended in the hydraulic fluid.

Fracture

The fracture on the steel stationary part of the seal in Fig. 34 indicates the seal assembly was improperly installed.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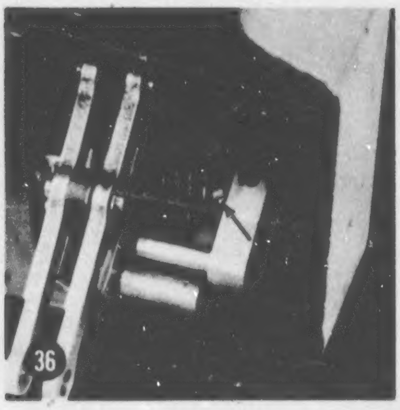
CHARGE PUMP ASSEMBLY

Fractured input flange

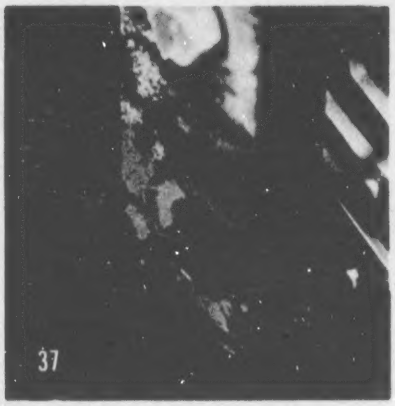
The fracture in Fig. 35 indicates the fitting was tightened too much. A severe blow to the adapter may also cause this type of failure.


36

DISPLACEMENT CONTROL VALVE

Broken Spring

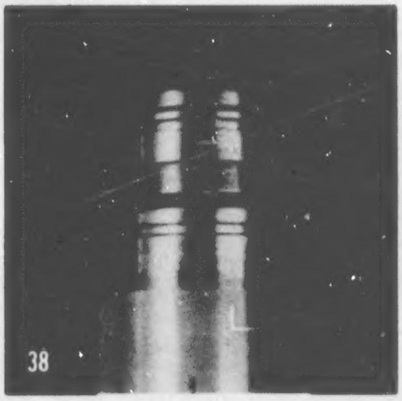
The spring pin that attaches the control shaft to the two pivots may fracture and result in a broken spring. (Fig. 36).


37

Broken control shaft

When the external portion of the control shaft is broken (Fig. 37) it is a result of either too much torque on the nut which retains the control handle or improper handling during shipping or operation.

IMPORTANT: All displacement controls are factory adjusted, locked and sealed with a cap noted at top of valve shown. Do not disturb this adjustment.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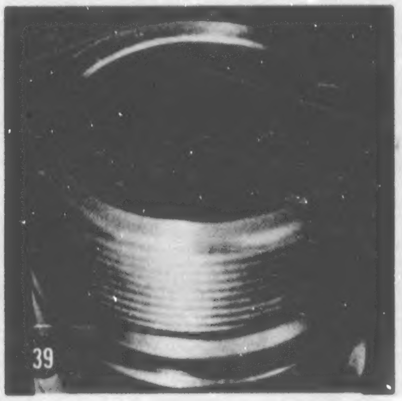
SERVO SLEEVE AND PISTON

Fracture

The fracture in the recess area (Fig. 38) usually indicates the sleeve was misused, such as dropping the unit on the servo sleeve.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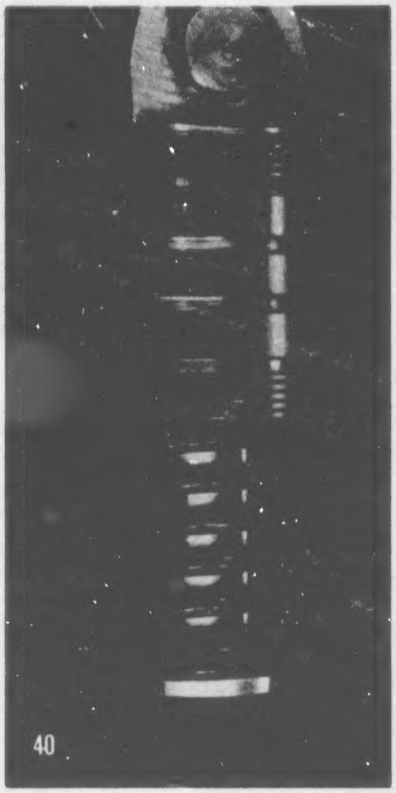
Scoring

Contamination usually causes scoring on the inside bore of the servo sleeve (Fig. 39).


40

Scoring in the servo piston is usually caused by abrasive contamination (Fig. 40). If scratches can be detected by feel with fingernail or lead pencil, the part should be replaced.

41

SHAFTS

Worn spline

A worn spline area usually results from an improper fit or misalignment of the mating coupling (Fig. 41).

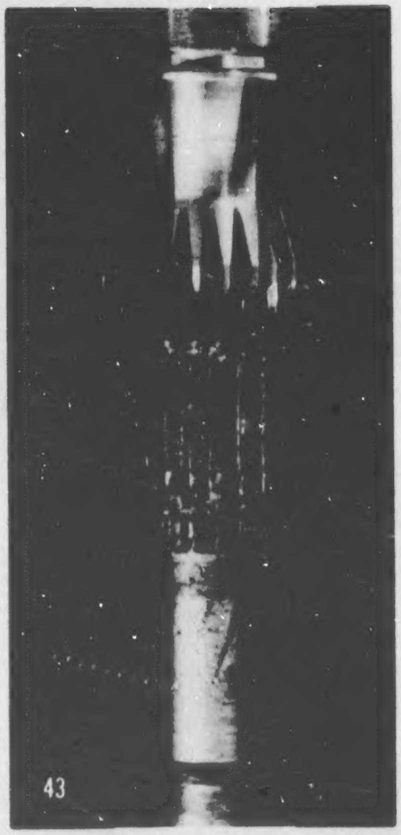
42

Fractured input taper

A broken taper (Fig. 42) is usually the result of an improper fit of the coupling to the shaft, or improper torque of the coupling retaining nut.

Worn spline

A worn spline (Fig. 43) normally is caused by excessive misalignment or torsional stress to the input shaft. Excessive load conditions may also cause this type of failure.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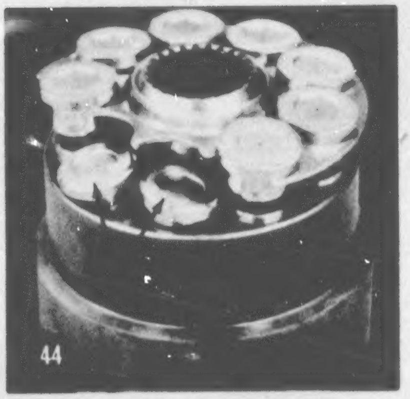
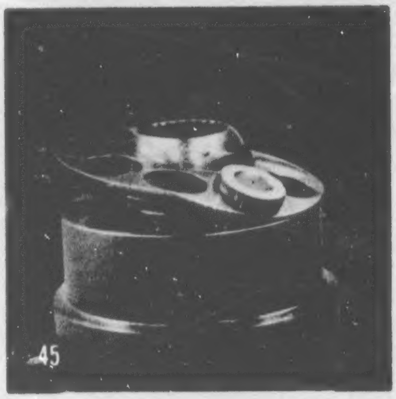

44

LIGHT DUTY HYDROSTATIC SYSTEMS

LOW INPUT SPEED OPERATION

The slipper thrust faces in Fig. 44 have rounded edges due to rolling. This can be caused by charge pump failure, or low speed operation. Restricted reservoir, line, or filter; low oil in reservoir; or internal leakage from wear or misassembly could also cause the failure. A broken retainer and stuck pistons result from continued operation with low system charge pressure.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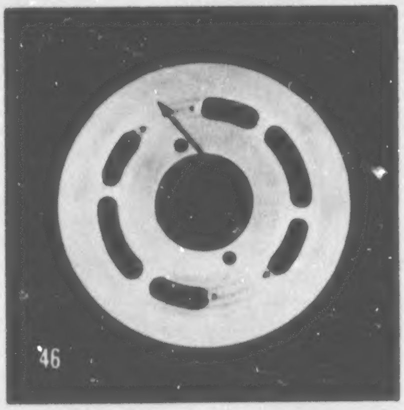
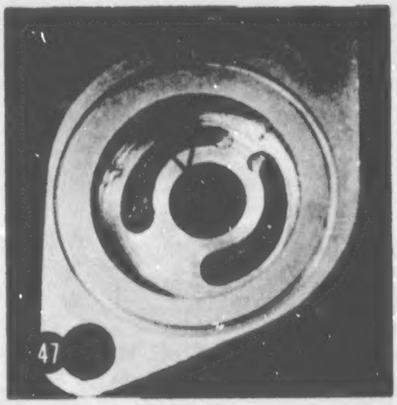

46

STUCK PISTON

Stuck pistons result from contamination in the system or damaged cylinder bore or piston surface. The slipper retainer in Fig. 45 is bent in the area of the stuck piston.

VALVE PLATE/CHARGE PUMP HOUSING

The valve plate, Fig. 46, and charge pump housing in Fig. 47 was scored, probably because of contamination in the system either prior to start-up or because the filter was not maintained.

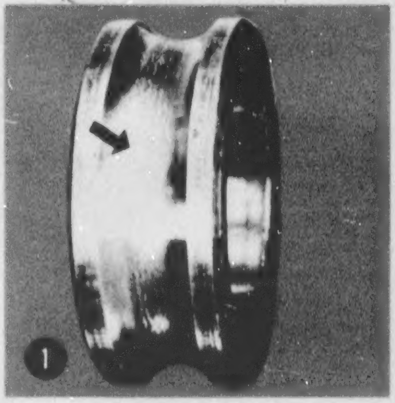

47

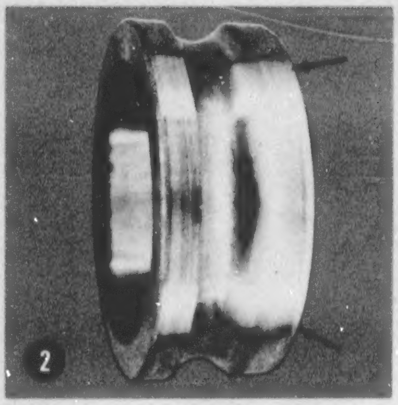
ANTI-FRICTION BEARINGS —Chapter 8

INTRODUCTION

Failures of anti-friction bearings are due to a variety of causes, most linked to the following:

- **Contamination**
- **Improper lubrication**
- **Improper installation**
- **Careless handling**
- **Distortion and misalignment**
- **Severe service**
- **Vibration**
- **Electric current**
- **Defects in bearing material**



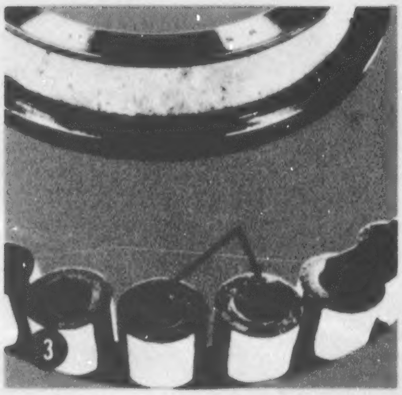


Contamination

Contamination is any foreign matter that will damage the bearing. Moisture and any type of abrasive, such as dirt or sand, will cause premature failure.

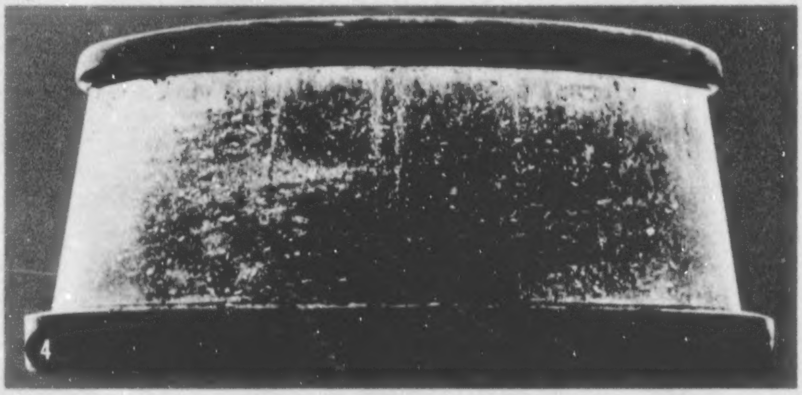
Abrasive contaminants and moisture rusted, scratched, and scored the bearing races in Fig. 1. This type of damage may be prevented by using the correct lubricant, keeping the bearing clean while handling it and using new or undamaged seals.

Fig. 2 illustrates the effect of coarse abrasives on the bearing raceways. Although it is difficult to picture, the dull, gray discoloration on the raceway surfaces contrasts with the bright finish of a new bearing.



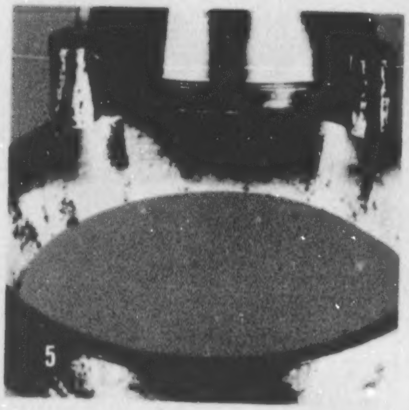
Foreign material caused excessive wear to the bearings in Fig. 3. The roller ends are worn down to the indent and the ribs are badly worn.

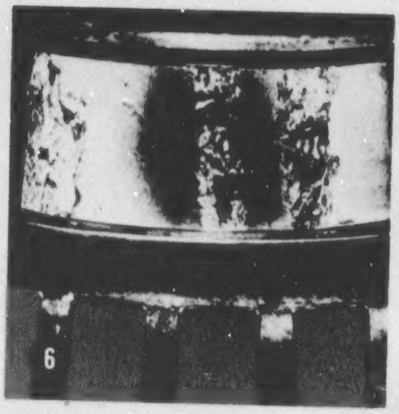
The second type of damage caused by foreign material is pitting. Pitting is a type of fatigue failure and appears when small particles of the bearing separates from the surface. As surfaces of mating parts come in contact, repeated stress on these surfaces can cause pitting.

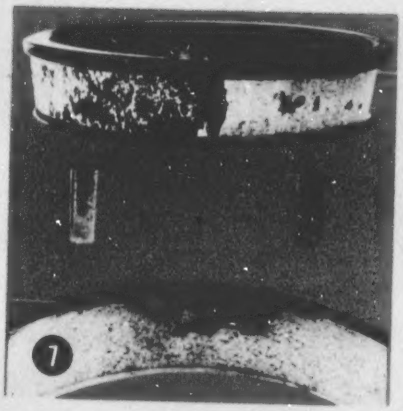


Metal chips or large particles of dirt remaining in improperly cleaned housings are the most usual causes of trouble.

Fairly large particles of metal or dirt bruised and pitted the bearing race in Fig. 4. Some of the indentations are so deep that the hardened surface of the bearing has fractured. The surface of the races would soon flake or spall (advanced pitting) with further operation of the bearing.





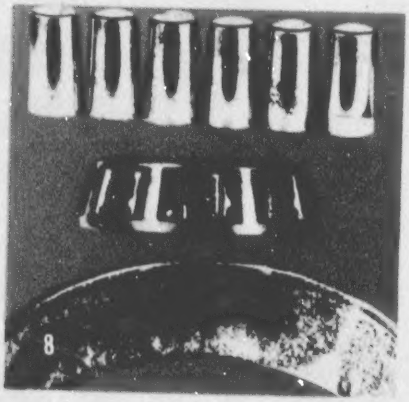


Rust or corrosion is a serious problem in antifriction bearings. The high degree of finish on races and rollers makes them quite susceptible to corrosion damage from water.

Corrosion is often caused by condensation of moisture in the bearing housing because of temperature changes. Moisture or water may get in through damaged, or worn seals. Considerable damage also results from improperly washing and drying bearings when they are removed for inspection.

Fig. 5 shows a bearing beginning to corrode while Fig. 6 shows more advanced damage from corrosion. The cones and the cups show spalling of the races at the areas where the heavy corrosion took place.

Advanced corrosion damage in Fig. 7 caused pits and spalls. Then as the metal continued to break down, as rollers hit the edges of the spalled areas, the complete raceway surfaces in the loaded area were broken down or spalled.

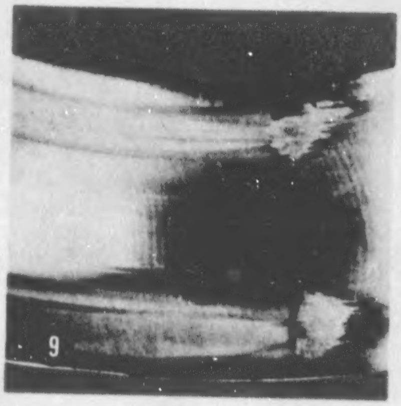


Water enters during unfavorable storage, through worn seals, or by leakage through gaskets or covers on housings. Results are heavy corrosion, or rusting, in Fig. 8.

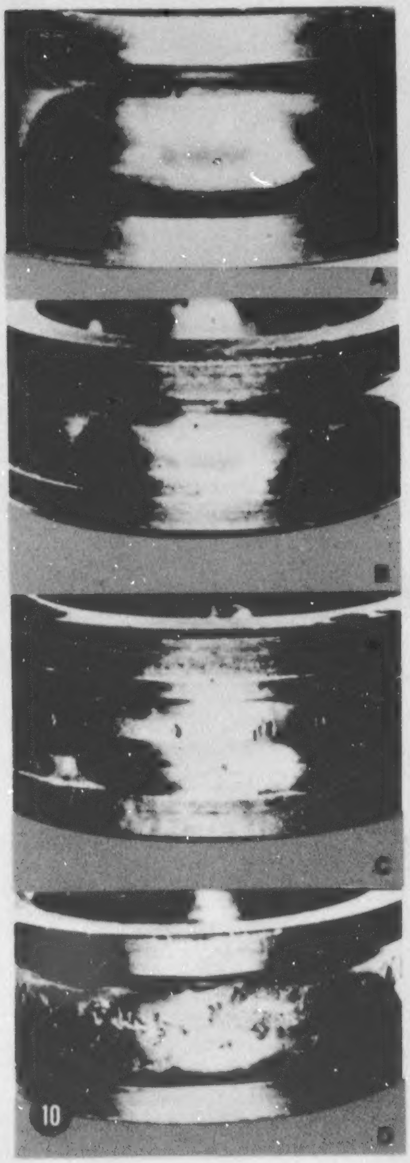
Improper Lubrication

Proper lubricant is important for a satisfactory bearing operation. It can be a complete lack of lubricant or too small a supply that causes bearings to fail. It may be the wrong kind of lubricant, or wrong grade or weight. Always use the lubricant specified by the manufacturer.

Too much lubricant that was too solid was used in the bearing in Fig. 9. The rolling elements slide across the surface, rather than roll, smearing the metal. The thick lubricant slowed the rolling elements enough to start the sliding. As the metal surfaces became smeared, the rate of wear increased. This damage can also result from inadequate lubricant.



Another form of surface damage is progressively shown in Fig. 10 a, b, c and d. The first visible indication of trouble is usually a fine roughening of the surface. Later spalling will begin from fine cracks.



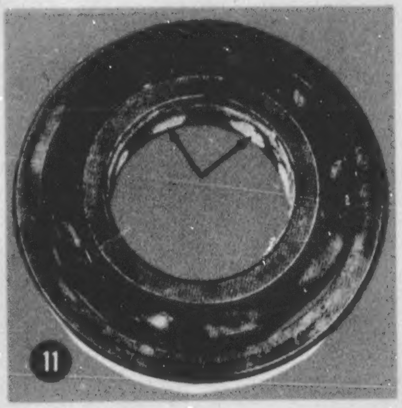
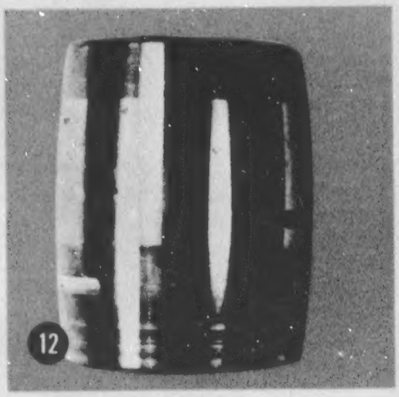
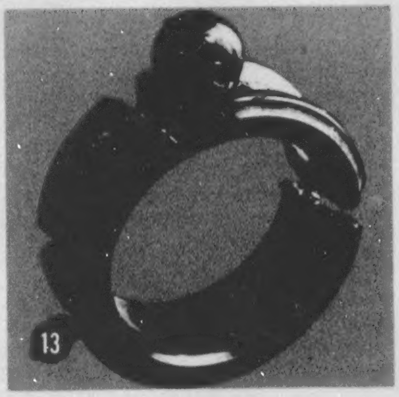
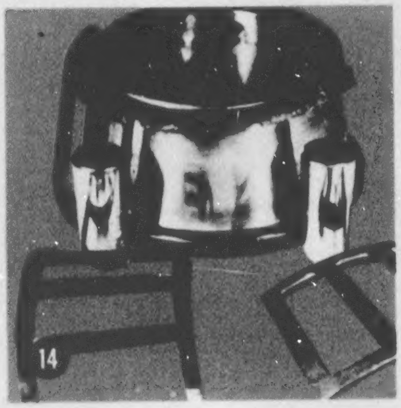


Fig. 11 shows discoloration and softening of the bearing due to excessive heat.

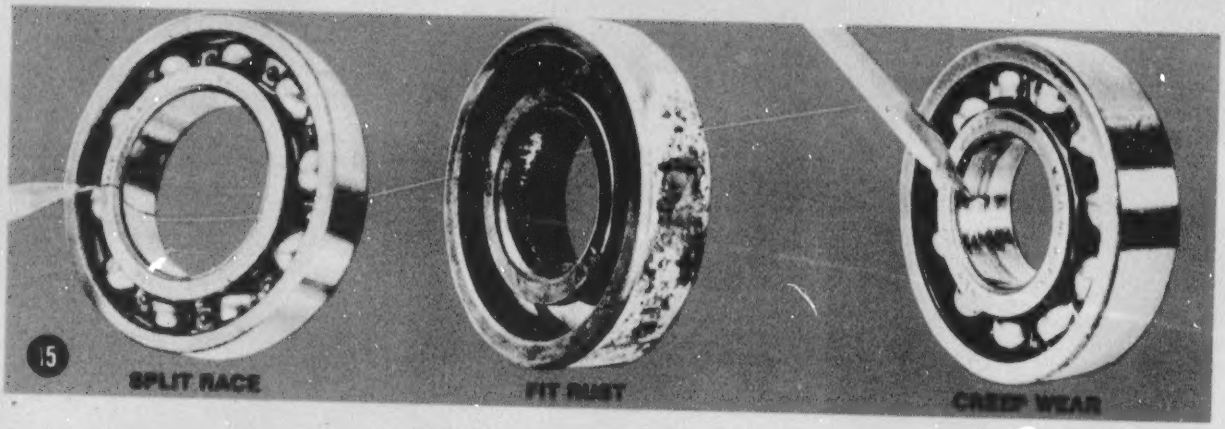




A bearing may glaze (Fig. 12) or balls may become welded to the ring (Fig. 13).



The broken cage in Fig. 14 was caused by intermittent lack of lubricant. At times, because of certain operating conditions, the oil fails to get to the bearing for a period long enough to cause light scoring of rollers and rib. This causes pressure on sides of cage pockets. After this has repeated a number of times the cage finally starts to crack and then break up as shown.

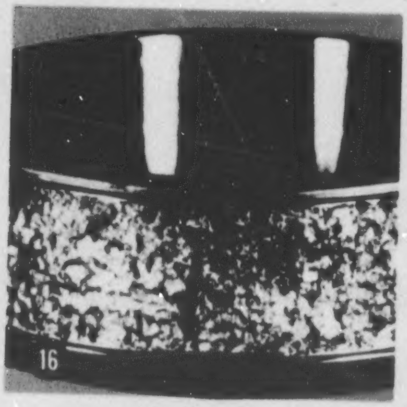


Improper Installation

Improper installation will also cause premature bearing failure. Excessive preload or tight adjustment can cause damage similar to inadequate lubrication damage. Frequently the two causes may be mixed so that a careful check is required to determine the real trouble.

Three types of damage resulting from improper installation are in Fig. 15. The first is a split race caused by forcing the bearing onto a shaft too large for the inside diameter of the bearing race. Next is the outer race of a bearing damaged by "fit rust" or fretting corrosion, which results when the outer race fits too loosely in its housing. Sanding or removing this rust will only increase the loose fit. The bearing must be replaced.

Creep wear, in the third example, is caused by too loose of a fit between the shaft and the inside bore of the bearing. As this wear progresses, the inner race turns faster creating more friction and heat and leads to eventual bearing failure.

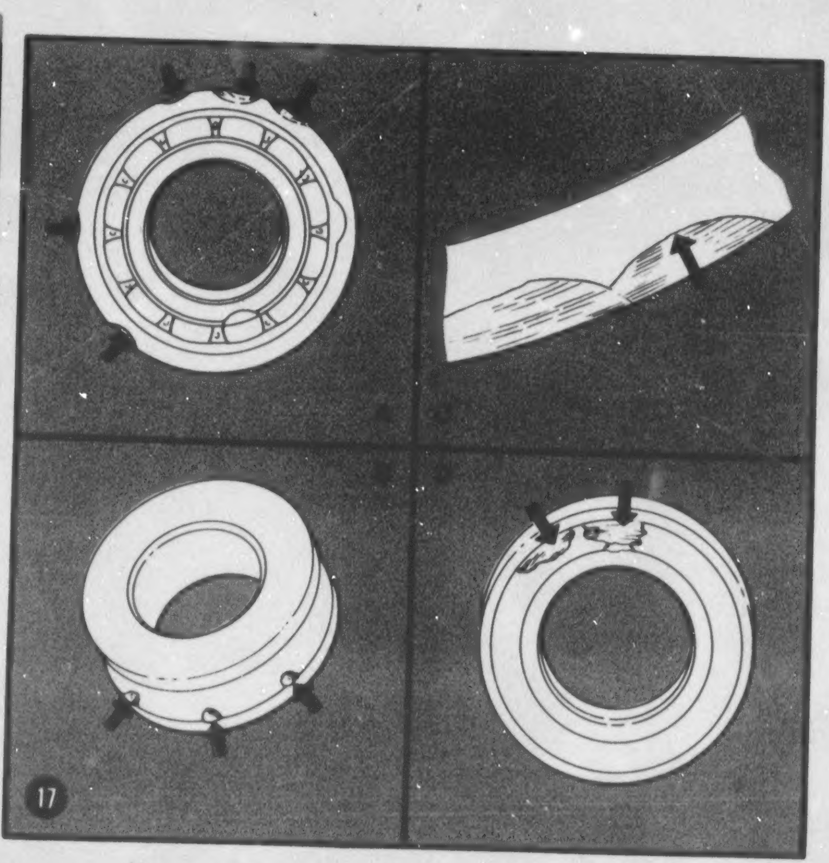


The bearing race in Fig. 16 is badly spalled from fatigue of metal. This fatigue occurred prematurely and could be eliminated by removing the preload or reducing it to the proper amount.

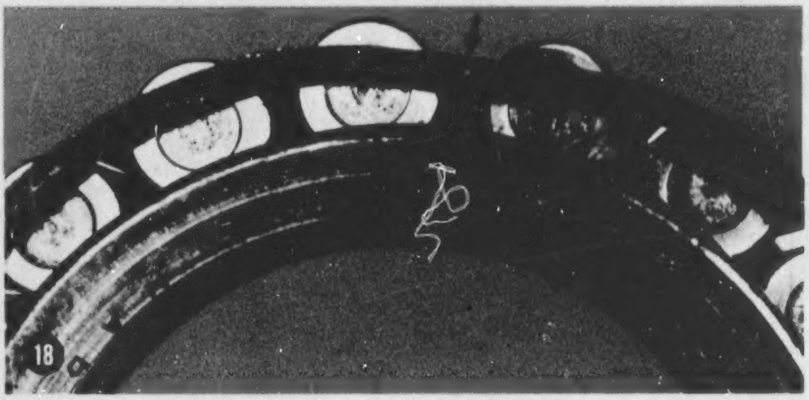
Careless Handling

Bearing damage can be caused by careless handling, by improper service technique, and by use of improper tools during installation.

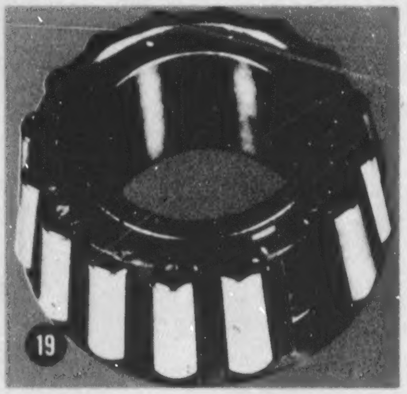
Damaged bearings in Fig. 17 received improper service. Example A shows nicks in an outer race cuased by using



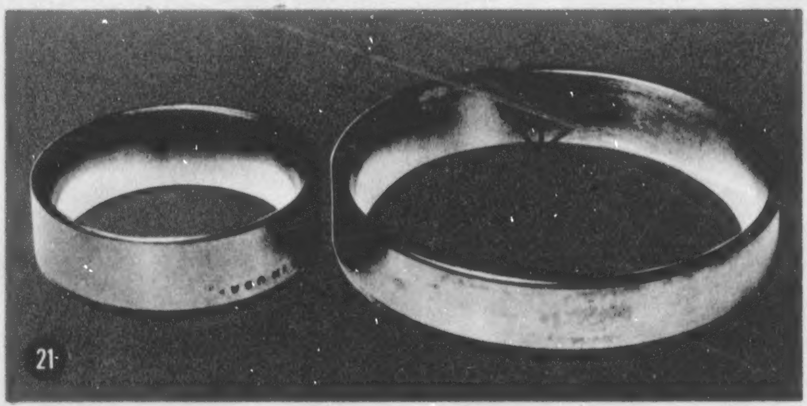
a hammering tool (drift) to drive the bearing. Example B is of cracks caused by striking the race with a hammer. The results of the hammering also damages the inner race as shown in Example C. When the race is struck a severe blow, the force is transmitted through the rolling elements to the other race and chips it. Another result of using improper tools is a damaged seal on the sealed bearing in D. A drift slipped and gouged this seal. The seal's effectiveness is reduced and the separator is probably put in a bind.

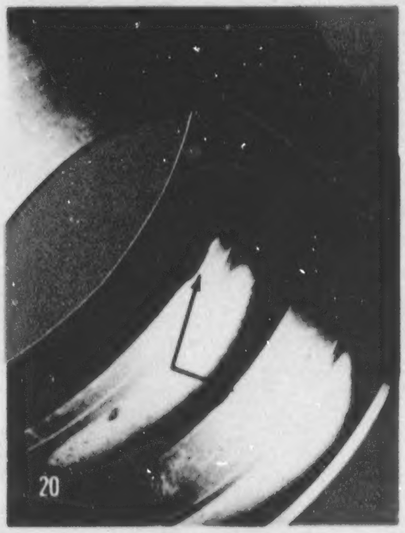


The bearing in Fig. 18 was dropped. It landed so that the cage was bent at the large end. This cage distortion causes the roller to bind in the cage and distort.

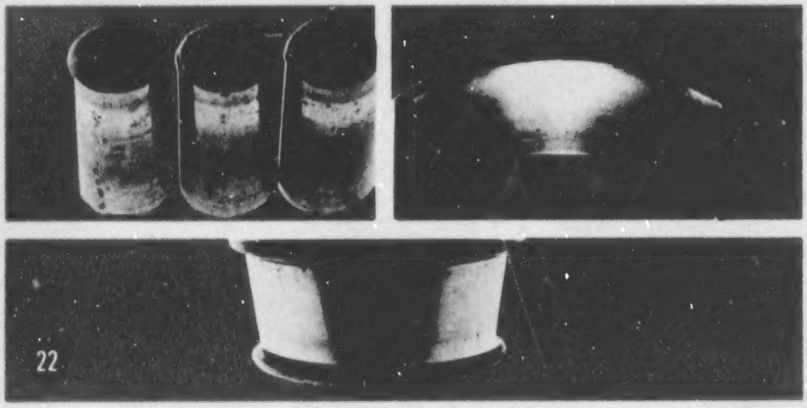


The cage in Fig. 19 was damaged during installation because proper tools were not used. It is apparent that a bar or drift was used against the cage instead of the cone face to drive the cone on the shaft.





Fatigue damage in Fig. 20 was from an impact during either handling or mounting. An impact leaves a depression that can initiate premature fatigue.



Nicks in cups in Fig. 21 and 22 were caused by the cone being in a cocked position with respect to the cup. The ends of some of the rollers dug into the cup surfaces. The roller edges were flattened and metal pushed up on the body of the rollers at these points. Because of the cocking action or tipping, the rollers were forced down on the edges of the cone race causing impressions at the extreme large and small ends of the cone raceway.

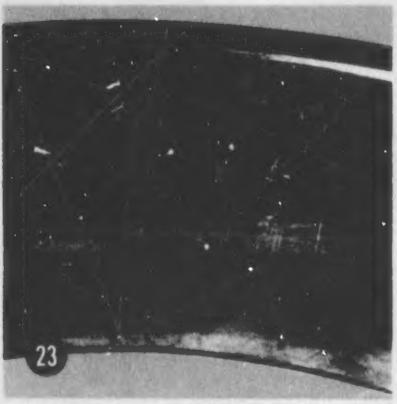
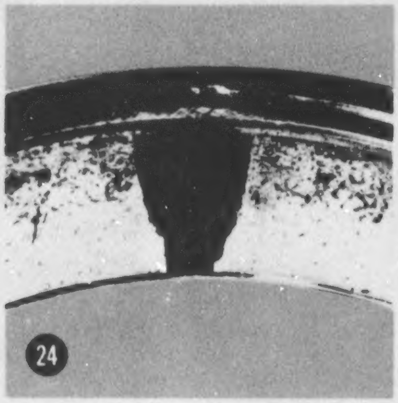
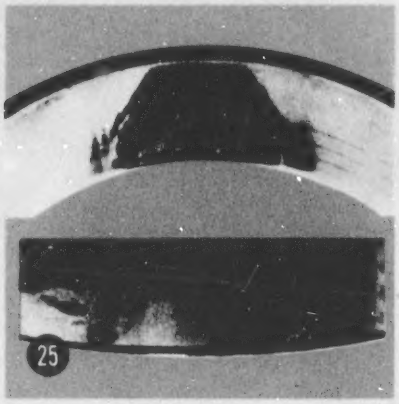


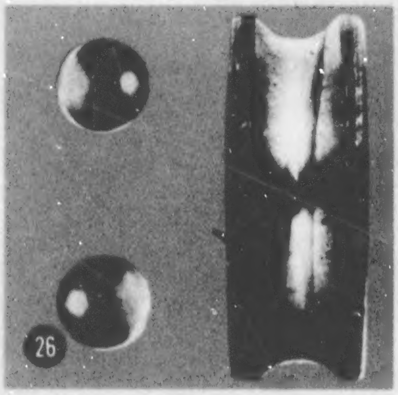
Fig. 23 shows how the bar or tool used to drive in the cup slipped and dug into the surface.



The marks in Fig. 24 extend out to the edge of the cup seat causing the high spot and the spall or fatigue at this point in the cup.

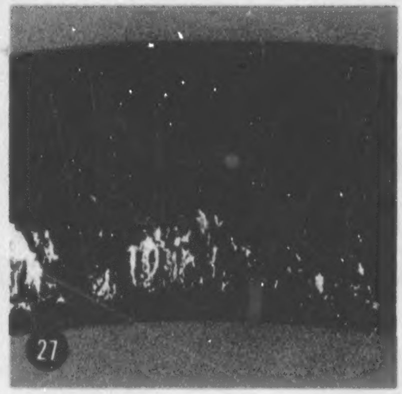


The inside diameter and outside diameter markings in a cup in Fig. 25 were caused by a high spot in the housing. The inside diameter is spalled at the area and the outside diameter shows heavy contact at the corresponding spot.

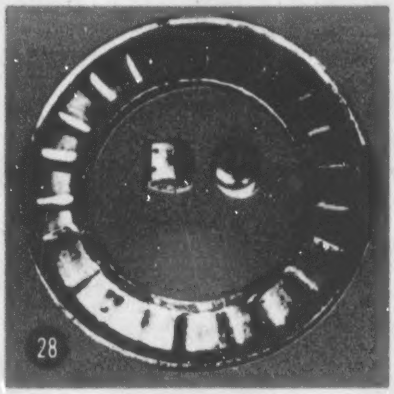


Misalignment

Misalignment is usually caused by a bent shaft, or foreign matter between the bearing and its seat. Notice the paths worn in the races in Fig. 26 and the worn shape of the balls. Misalignment in roller or needle bearings usually results in extreme pressure on the races and rollers, and premature fatigue failure. The cause of failure must be determined and corrected or the same damage will result when new bearings are installed.



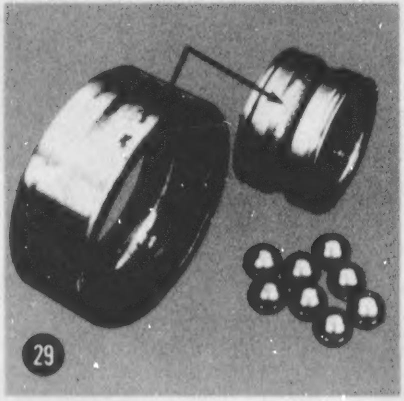
Excessive end play in a bearing resulted in the condition in Fig. 27.



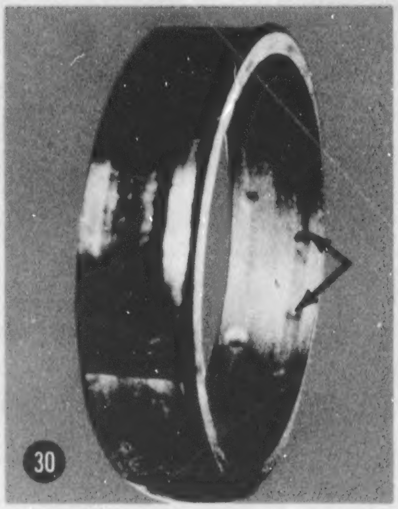
Severe Service

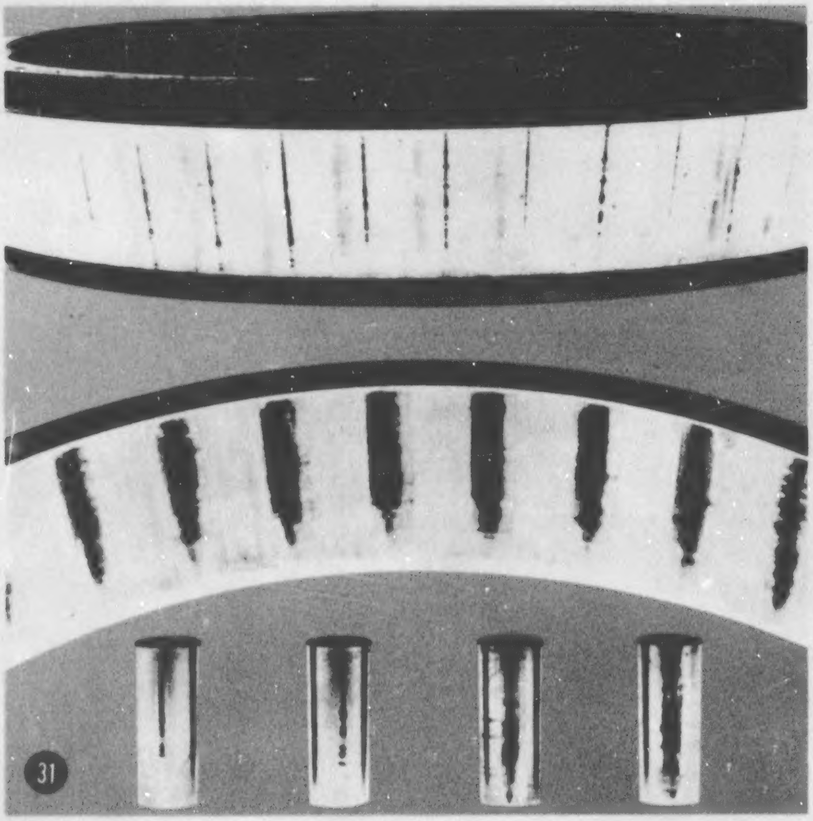
Extremely heavy impact loads of short durations can result in impressions in the bearing races and sometimes even fracturing the races and rollers.

If trust bearings are set with end play, there is a pounding action set up as the wheel goes over uneven surfaces. These rapid short impacts pound the rollers into the races and ultimately will fracture the race (Fig. 28).



The first indications of fatigue failure may be noisy running and increased vibration. The bearing races show the metal surfaces of the races have flaked away (Fig. 29). This flaking is caused by the effects of excessive speed and load.



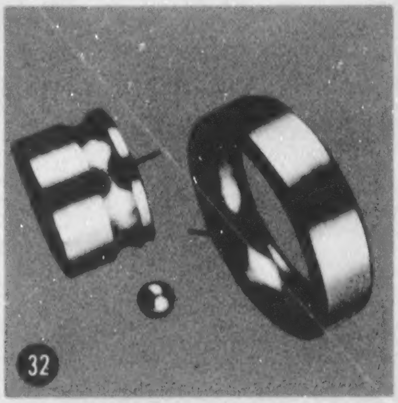


This wear is caused by the rollers sliding back and forth on the race while the bearing or race is stationary. A groove is worn into the race by this sliding of the roll back and forth across the race. Vibration causes the sliding movement. The vibration present may cause enough movement to produce some of this wear.

The heavier markings and particularly the deeper and sharper narrow grooves in Fig. 31 will cause noise and roughness in the bearing.

Vibration

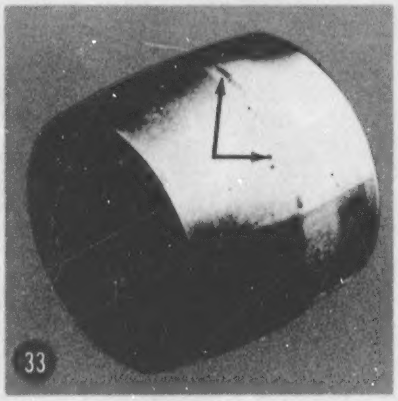
Most anti-friction bearings are rolling while under load. The bearing in Fig. 30, however, was stationary while subjected to vibration. The depressions result from a combination of wear and impacts caused by this vibration. When this bearing is subjected to a rolling load, it will fail rapidly.



Electric Current

Where bearings are used in the presence of electricity, potential damage can occur if the electrical current passes through the bearing.

Several electrical arcs that occur as the bearing turns melt the surface metal and lead to bearing failure (Fig. 32). This pattern normally repeats itself many times around the diameter of the ring and race.



Electric pits occur each time the current breaks in its passage between raceway and roller. Fig. 33 shows a series of electric pits. Amperage rather than voltage governs the amount of damage and both alternating and direct current cause damage.

The cause of the electrical leak must be found and corrected or it will occur again with a new bearing.

BELTS AND CHAINS — Chapter 9

INTRODUCTION

Belts and chains are flexible members for transmitting power. They have these advantages over other power transmitting devices:

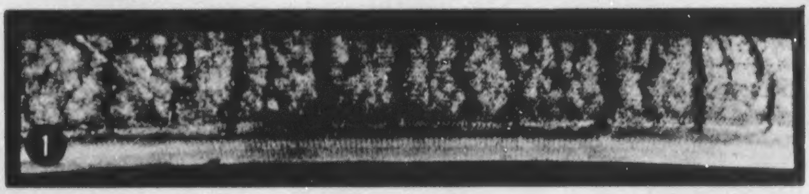
- *They are suitable for relatively large center distances*
- *Belts absorb vibration and shock*
- *Belts may be quiet*
- *They have a long life, if properly maintained (usually not longer than other devices)*

V-BELTS

Belts can fail by wearing out, as a result of damage, or they can fail prematurely as a result of defective material in the belt.

A discussion of V-belt failure follows.

- **Cracking**
- **Rupture**
- **Tear**
- **Burn**
- **Gouges**
- **Wear**
- **Internal Cord Failure**
- **Cuts**
- **Peeling, Fraying, Chewing**



Cracking

Excessive cross-cracking on the base of a belt having little or no side wear (Fig. 1) indicates a defective belt only if it has run a very short time. This is a normal failure for belts that have run a long time at light load.

This is frequently caused by the belt slippage causing heat build-up and gradual hardening, or by the belt running on too sheaves that are too small (Fig. 2). This is also a normal failure for belts that have run a long time.

Rupture

The type of wear in Fig. 3 can be caused by operating a belt over badly worn sheaves, too much tension forcing the belt down into the grooves, or objects falling onto the sheave groove while the drive is operating.

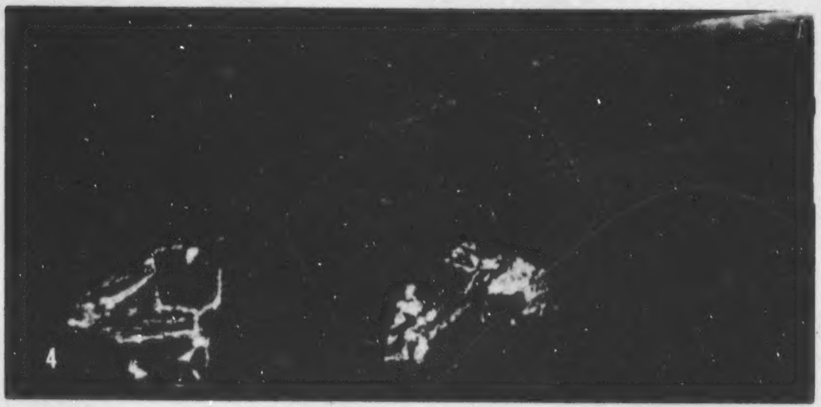
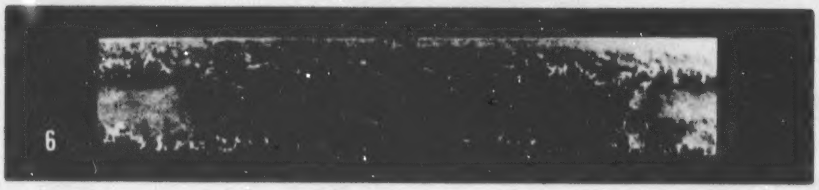


Fig. 4 shows a belt pulled apart. The cause of it could have been an extreme shock load, the drive being untreme shock load or the belt coming off the drive.

Ruptured cords are shown in Fig. 5. Possible causes are foreign material damage or too much tension.



Tear

The cover tear of the belt in Fig. 6 is an example of damage caused by the belt accidently coming into contact with some part of the machine. In many cases, such failure is due to belts running too loose, allowing them to throw out centrifugally and rub on parts of the machine.

Burn

The burned sides and bottom of the belt in Fig. 7 was caused by the belt slipping under a starting or stalling load.

The belt in Fig. 8 shows the results of a spin burn. The driven pulley stalled from an overload or improper belt tension burning the belt when the drive sheave continued to run.

Gouges

Except for the gouged edge, the entire circumference of the belt shown in Fig. 9 is in new condition. Damage was caused by either a damaged sheave or interference with some part of the machine.

The failure in Fig. 10 was caused by the gouge. Shock load at time of damage broke or weakened the belt causing the failure.

10

The belt in Fig. 11 shows a gouge mark on the inside center of belt and the wrapper has started to peel. This indicates that some foreign object came in contact with the belt while in operation, causing the damage.

11

Wear

The badly worn belt in Fig. 12 is the result of long operation without enough tension. The sides are worn and slightly burned completely around the belt.

12

Fig. 13 shows severe wear on corners and surfaces of belt caused by the belt rubbing on some obstruction.

13

Worn belt sides, due to constant slip, are shown in Fig. 14. The belt was probably improperly tensioned.

14

15

The extreme wear pattern on the top corner and bottom corner of the belt in Fig. 15 indicates the belt was rubbing on some obstruction.

16

The wear in Fig. 16 was due to the misalignment of the drive. Notice how both plys have been completely worn off of one sidewall while the other side of the belt shows normal wear.

17

Internal Cord Failure

The belt in Fig. 17 was overstressed and the inner cords were broken, causing premature failure. This belt was damaged during installation when it was roped over the sheave flange without releasing the tension.

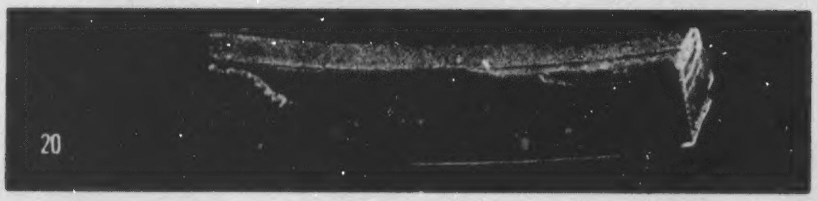
18

Cuts

The bottom cut on the belt in Fig. 18 could have been caused by the belt running over the sheave and coming off, foreign material falling into the drive making the belt come off, or the belt being forced over the sheave flange during installation without slacking off the drive.

19

The cut on the corner of the belt in Fig. 19 was caused by a sharp object, such as a belt guide coming into contact with the belt while in operation.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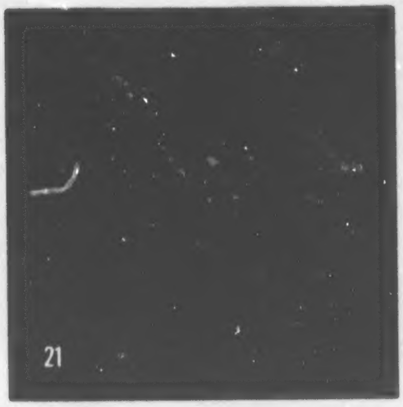
The belt in Fig. 20 was damaged by the belt climbing out of a sheave groove while in operation. Notice the large section of belt cut out along the lower inside of the belt. The clean cut section indicates the belt was very tight when it climbed on the sheave.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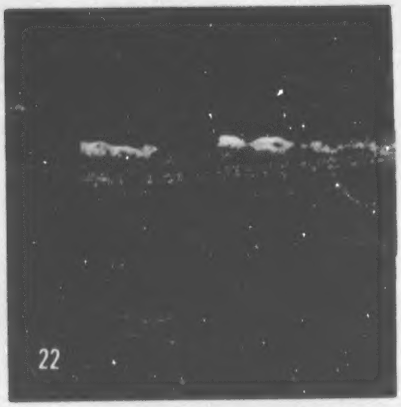
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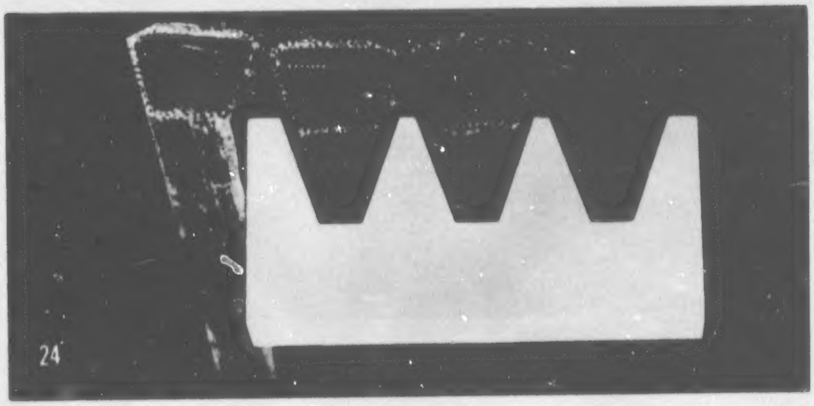
Peeling, Fraying, Chewing

The outer wrapper in Fig. 21 has started to peel on the inside of the belt. This type of damage could occur during installation or in service due to belt climbing over the sheave flange caused by improper adjustment or alignment.

The inside cover in Fig. 22 has started to fray indicating the bottom of the belt was operating against some foreign object in the sheave grooves, such as mud, stalks or the sheave groove was wrapped with weeds.

23

The belt in Fig. 23 shows that some foreign object entered the sheave, chewing up the cover or wrapper and causing the belt to turn over in sheave grooves. The lower portion of belt shows wear indicating the belt had been run in a turned over position in the sheave. This staggered pattern of cuts may have occurred when the belt turned over.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BANDED V-BELTS

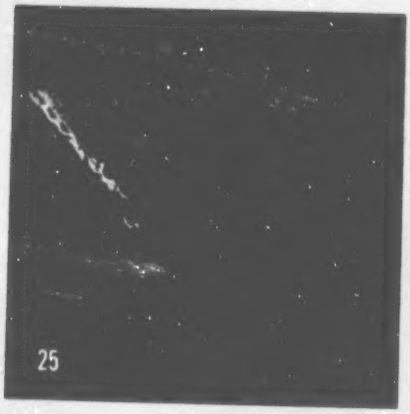
Banded V-belts were developed to solve troublesome problems on those drives where belts whip, turn over or come off drives.

Banded V-belts stay on the drive, eliminating downtime as well as the maintenance cost involved in re-installing belts on the sheaves. These belts consist of multiple V-belts permanently vulcanized together with a tie band to minimize the possibility of its turning over or coming off the sheaves.

Banded V-belts, however, have some wear problems which are unique.

Riding Outside of Sheave Groove

Possible misalignment, lack of tension, or foreign object forced one strand of the belt from sheave groove (Fig. 24).



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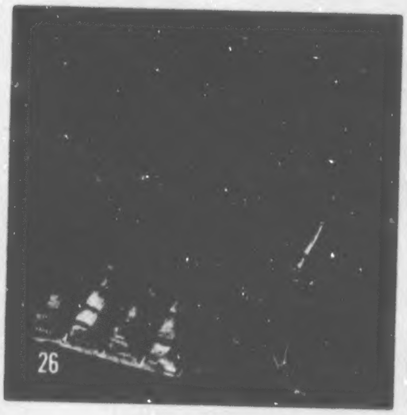
Riding outside of sheave grooves is a possible cause of the belts in Fig. 25 separating completely from the band.



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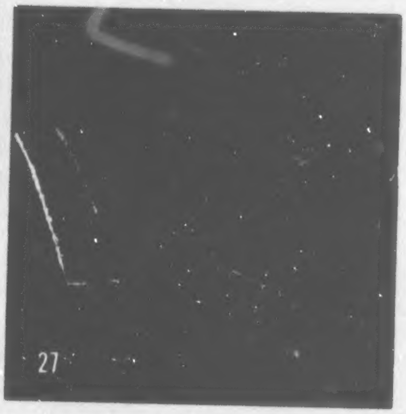
Bottoms of Belts Cracking

The belts in Fig. 26 are cracked by running on sheaves that are too small, heat build-up caused by slippage and gradual hardening of the undercord, or have run a long time.



27

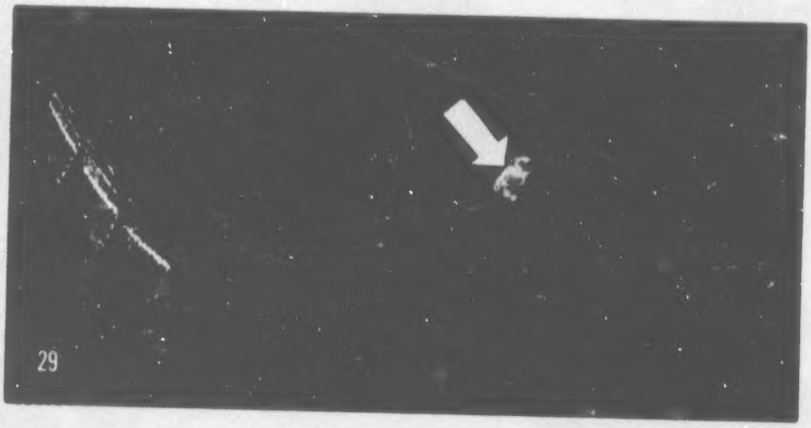
Top Of Band Frayed, Or Damaged

The damage in Fig. 27 is caused by an obstruction on the machine interfering with normal belt operation.

28

Band Separating From Belts

Worn sheaves probably caused the damage shown in Fig. 28.



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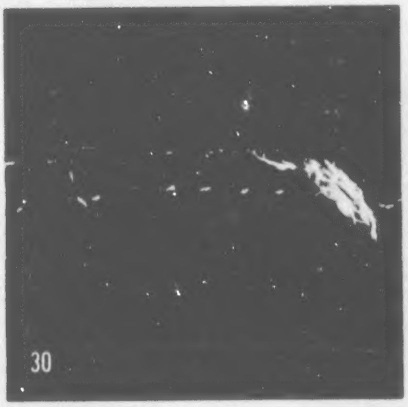
Holes Or Blisters In Tie Band

Accumulation of trash and foreign material between belts caused the damage shown in Fig. 29.



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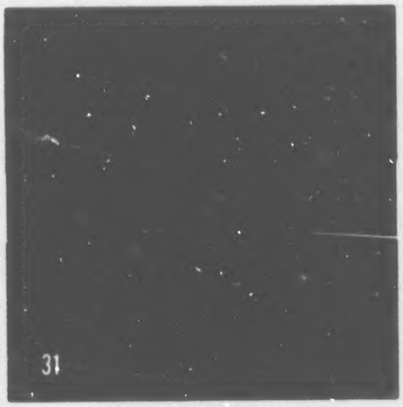

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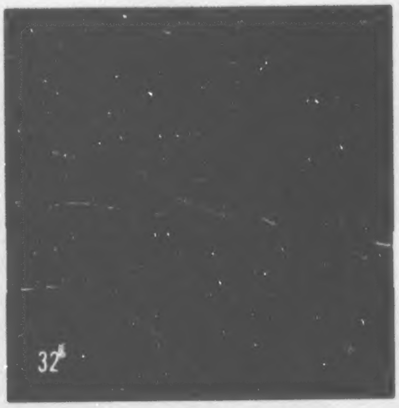

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SPECIAL V-BELTS

The following illustrations refer to the failure of V-belts in the snowmobile power train.

Frayed Edges

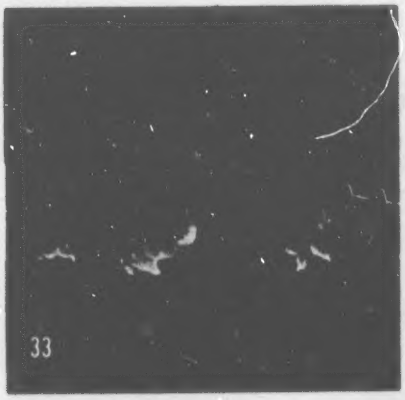
If drive belt wears rapidly exposing frayed edge cord (Fig. 30) belt is misaligned. Engine mounting bolts could also be loose allowing engine to twist and misalign belt.

Narrow Wear In One Section

If drive belt is worn narrow in one section (Fig. 31), excessive slippage is indicated due to a stuck or frozen track. Too high an engine idle speed could also be indicated if several narrow sections are evident.

Drive Belt Disintegration

Drive belt disintegration (Fig. 32) could be caused by a misaligned belt, using an incorrect belt or oil on sheave surfaces. If badly misaligned, drive belt will roll over at high speed causing belt disintegration.



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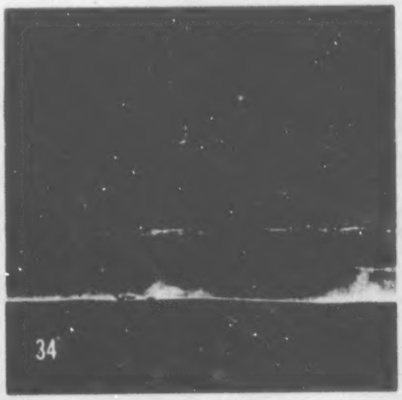

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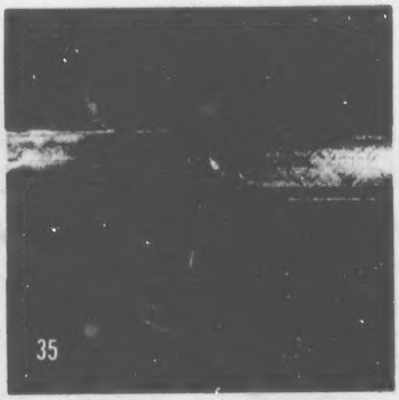

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Drive Belt With Sheared Cogs

A drive belt having sheared cogs (Fig. 33) could indicate violent engagement of drive sheave caused by binding or improperly installed drive sheave components. This is typical flex fatigue for this construction.

FLAT BELTS

Common wear on flat belts is shown in the following illustrations:

Flat Belt Tears

An improperly aligned pulley causes a flat belt to climb the inner end of the engine drive pulley, tearing the edge of the belt (Fig. 34). One of these tears may eventually cause the belt to tear completely through.

Flat Belt Burn

The shiny appearance and badly burned area (Fig. 35) were caused by operating the drive belt too loosely. Note the notch in the edge of the belt where it slid sideways against the flange of the drive pulley, while slipping and burning the center section.

CHAINS

The principal forms of chain failure:

- **Wear**
- **Fracture**
- **Corrosion**

Wear Of Chains And Chain Parts

As chains wear and stretch they do not mate properly with their sprocket teeth.

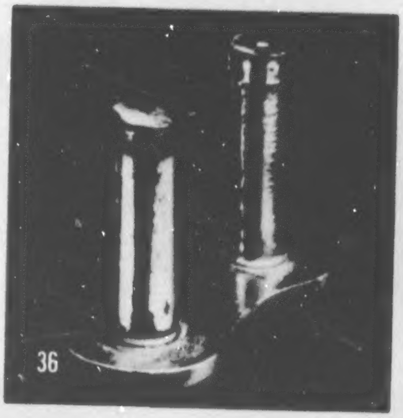
The wear rate of a chain depends upon lubrication and the abrasives present (Figs. 36, 37, 38, 39). Discolored pins (brown or black) or corrosion are signs the chain joint has not received sufficient lubrication.

Galling (Fig. 39) is a severe form of wear when the mating surfaces weld and then break away. If chain speed is greater than recommended, it is impossible to get lubrication into the chain joint and galling will occur.

Fracture Of Chains And Chain Parts

Link breakage is generally caused by:

- *Excessive vibration*
- *Chain jumping the sprocket teeth*
- *Out of parallel shafts*
- *A foreign object entering between the chain and the sprocket teeth*
- *Excessive loads*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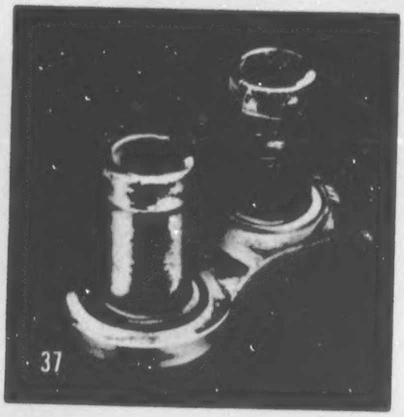
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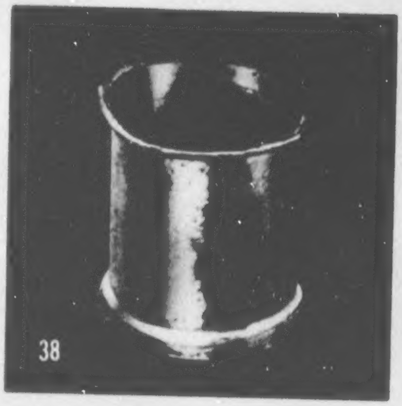
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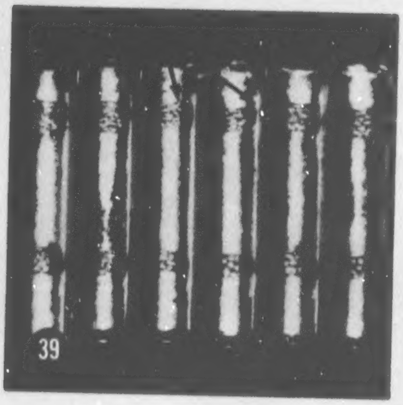
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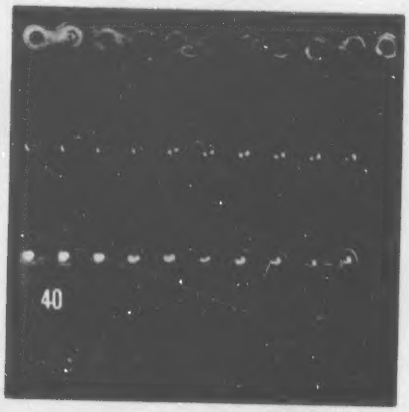
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Corrosion Of Chains And Chain Parts

When a chain is subjected to corrosion in the field, its mechanical properties are impaired. There is usually a general roughening of the surface, such as pitting, and the formation of rust (Fig. 40).

TRACKS AND TIRES — Chapter 10

TRACKS

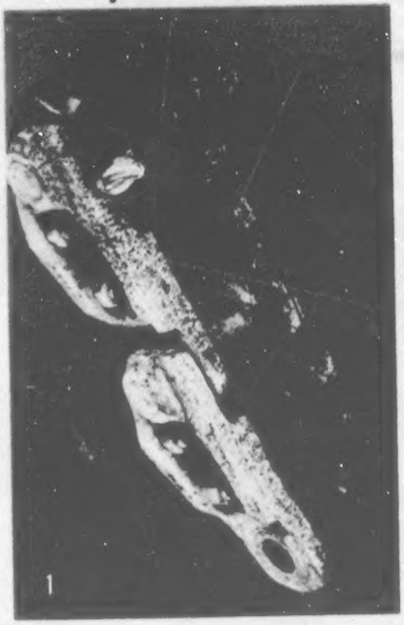
This section describes the failure of the following track undercarriage parts:

- **Links**
- **Pins and bushings**
- **Sprockets**
- **Rollers**

LINKS

If the link pin boss comes in contact with the roller flange, wear occurs on both the link and the roller flange. Severe wear (Fig. 1) may allow pins to become loose and fall out.

Loose hardware between the link and the shoes also wears links and can enlarge bolt holes.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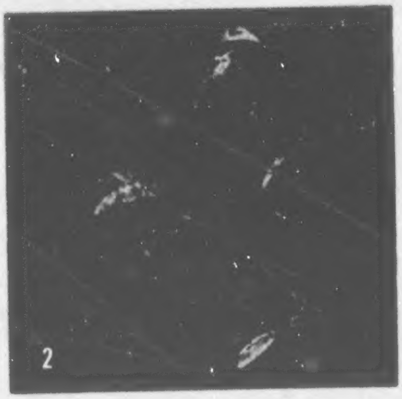
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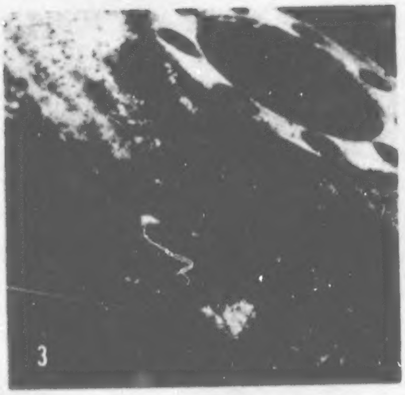
PINS AND BUSHINGS

A completely worn bushing results from not turning after one side wears. Fig. 2 shows both a bushing broken through and one not yet broken (right).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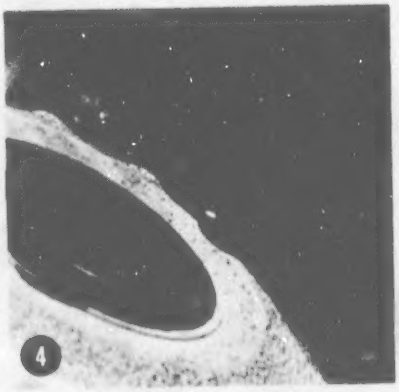
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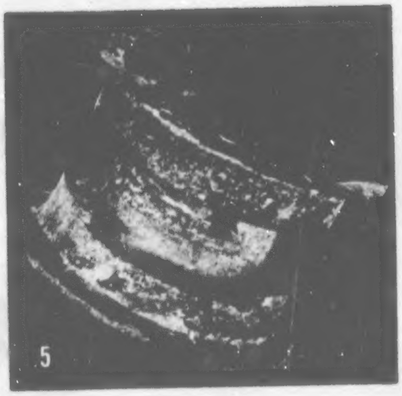
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SPROCKETS

Sprocket wear depends on the loading, terrain, abrasiveness and moisture content of the soil. Sprockets wear most uniformly and slowly if the track pitch and sprocket pitch are the same, as is the case with all new parts.

If the sprockets become packed with dirt or clay the sprocket tooth tips wear due to a mismatch between the sprocket and track pitch. Also, with the increased track pitch caused by pin and bushing wear, the bushing climbs out over the sprocket tips causing wear (Fig. 3).

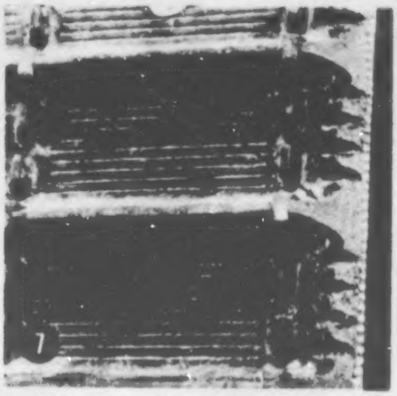
Fig. 4 also shows excessive wear. The even wear across the sprocket indicates the sprocket may have been reversed. Chips in the teeth indicate the sprocket must have been hitting the rear roller or a stone lodged in the track frame.

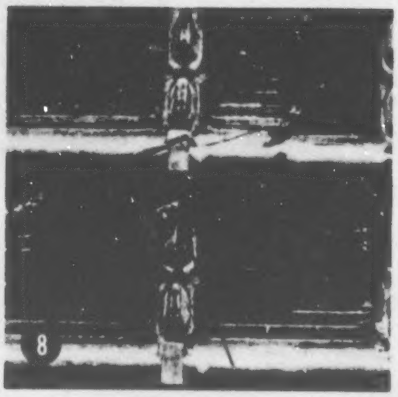
Sprocket and other track parts wear more quickly through reverse and side hill operation and misalignment. When the bushings slide across the root of the sprocket teeth, or from side to side, it wears the sprocket root. If the bushings are loose they will rotate while entering and leaving the sprocket causing rotating wear.

ROLLERS

Rollers wear internally or externally. The internal roller components are permanently lubricated and sealed and should last the life of the roller, however, side hill operation or parking sideways on a slope puts pressure on the seals and can cause a loss of lubricant.

Heavy loading on the flange from the side hill operation causes the wear. Tread wear results as the links rub against the roller tread. Fig. 5 shows excessive tread wear and damage from an impact (large arrow). The top flange is also thinner, probably result-





ing from side hill operation or track misalignment (small arrows).

Fig. 6 shows a carrier roller with excessive wear caused from track misalignment, side hill operation or a bent shaft.

SPECIAL TRACKS

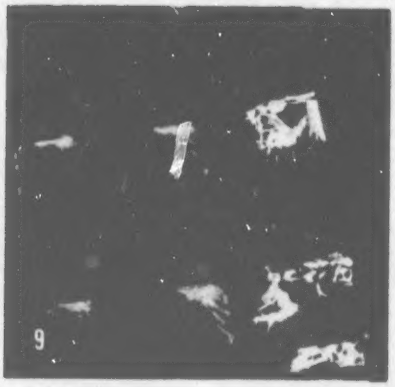
The following section refers specifically to snowmobile tracks:

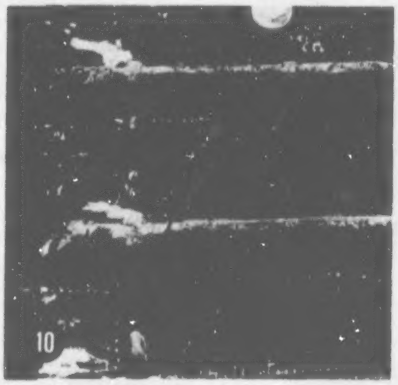
CABLE AND EDGE DAMAGE

Each track has two woven steel cables running completely around the track. They may be ripped partially out or, if the entire edge is damaged, may be completely gone. Damage is most frequently caused by tipping the snowmobile on its side to clear the track or allowing the track to come in contact with an abrasive surface (Fig. 7).

OBSTRUCTION AND IMPACT DAMAGE

Apparent cuts, slashes or gouges in the surface of the track (Fig. 8) are caused by obstructions such as broken glass, sharp rocks or buried steel. This commonly occurs during rapid acceleration or side skidding over foreign objects.





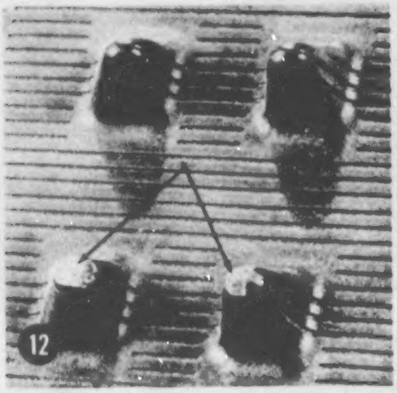
Impact damage to the edge of the track (Fig. 9) is usually caused by frequent riding on rough or frozen ground or on ice. Insufficient track tension, allowing the track to "pound" against the track stabilizers, may also cause impact damage. Excessive travel over buried logs may lead to damage.

FACE DAMAGE

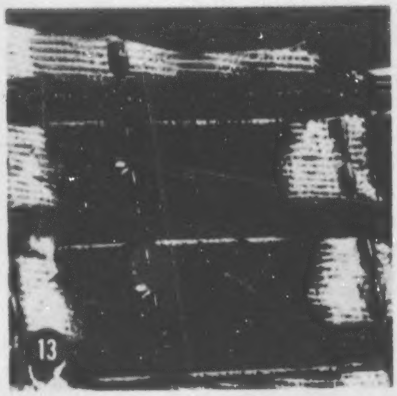
Excessively worn track face or grouser bars (Fig. 10) are caused by operating on extremely rough and dry terrain such as non-snow covered fields, railroad and highway right-of-ways, and gravel roads.

LUG DAMAGE

Damage to the sides or rear edges of the lug (Fig. 11) is usually caused by lack of snow lubrication and excessive track tension.



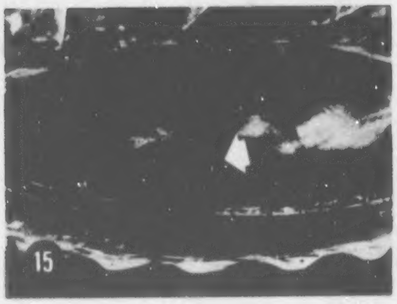
Ratcheting damage to the lug top (Fig. 12) results from insufficient track tension, pulling too great a load, or frequent prolonged periods of rapid acceleration.



TRACK TENSION DAMAGE

Overtightening the track causes the three rear idler wheels to push excessively into the track. This will cause the fabric to break (Fig. 13) and the track to become "fuzzy" on the face from rear idler wheel pressure.

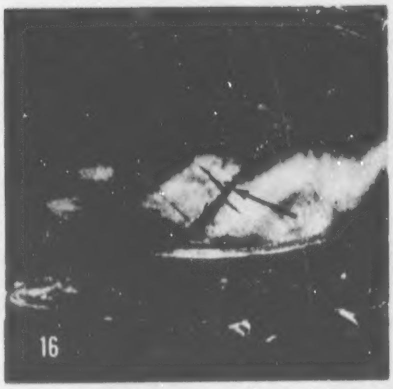
Operating with a loose track allows the outer edge to flex (Fig. 14). Some wear on the driving lugs may also be visible. Excessive weight without heavy-duty rear suspension can also cause the track to flex and break the edge.



TIRES

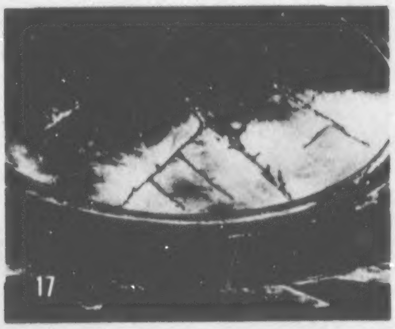
This section describes the following tire failures:

- **Fabric breaks**
- **Rubber checks**
- **Wear**
- **Tread wiping**
- **Tread and sidewall cuts**



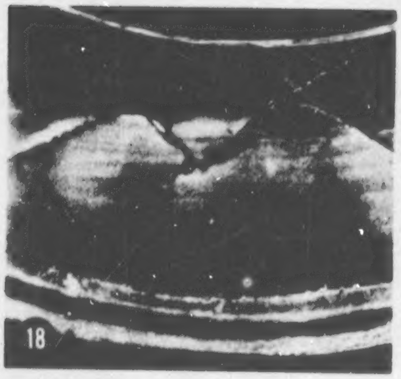
FABRIC BREAKS

The small fabric break in Fig. 15 can be repaired. Most fabric breaks are caused by hitting some object, which puts too much shock on the fabric (Figs. 16 and 17).

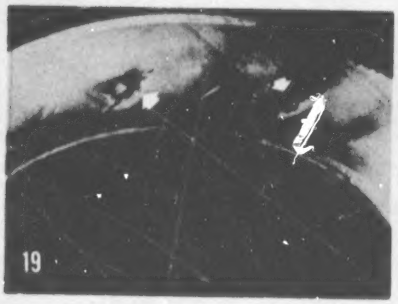


The force is greater if the impact occurs at high speeds, or if the tires are overinflated (Fig. 17). At high inflation pressures, damages may occur which later result in a large "X" or diagonal break which may extend from bead to bead.

Even at correct tire inflation, a severe localized blow, such as contact with a sharp rock or tree stump, can result in cord breakage like those shown.



A special kind of tire break is caused by water freezing and expanding in the tire (Fig. 18).



On farm tractors, the furrow tire may be distorted by the tilt of the tractor. This puts a severe folding action on the tire, especially if the inflation is too low, causing the inner sidewall of the tire to finally separate in a series of breaks (Fig. 19).

This action may also cause a series of cracks at the edge of the tread bars (Fig. 20), sometimes extending into the sidewall as shown.

RUBBER CHECKS

Small checks or cracks on the rubber sidewall (Fig. 21) are usually caused by tires inflated to high pressures. Normally this is an appearance condition only and will not affect the service life or the tires.

WEAR

Tractor tires with too few wheel weights or too much inflation will wear the tread bars rough, or will snag and cut the bars, when subjected to severe service on abrasive surfaces. Sudden engagement of the clutch in starting also causes this type of tread wear. Tread bars are cut and worn on the leading or forward edge (Fig. 22).

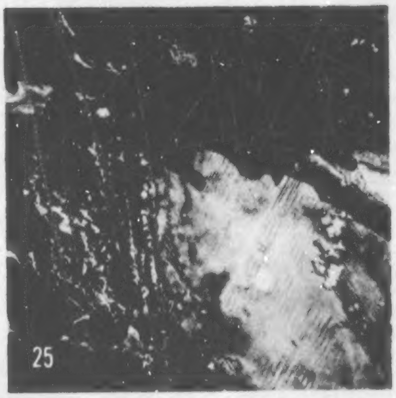
Operating a tractor tire over corn stubble (Fig. 23) causes wear and can puncture the tire. To avoid or limit stubble damage, adjust the track width of the rear tires so neither tire rides over the stubble. Avoid spinning the wheels where they do contact the stubble.

24

TREAD WIPING

Tractor tires operating on hard roads with low inflation pressure cause an undesirable distortion of the tire. The tread bars "squirm" while going under and coming our from under the load.

On abrasive or hard surfaces, this action "wipes" off the rubber of the tread bars or lugs and wears them down prematurely and irregularly (Fig. 24).



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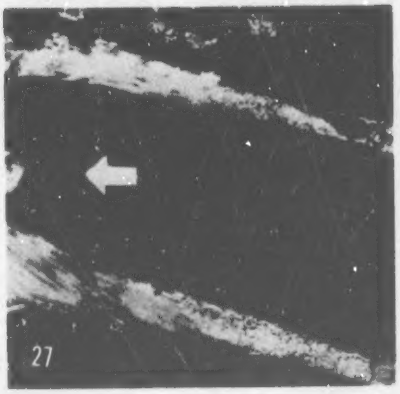
TREAD AND SIDEWALL CUTS

Many tires injured by cuts or snags (Figs. 25 and 26) can be repaired and continued in service. Cuts or breaks that enter into or expose the cords in the body of the tire should be repaired promptly. If not repaired moisture and foreign material can enter the injury and deteriorate the cords (Fig. 27).



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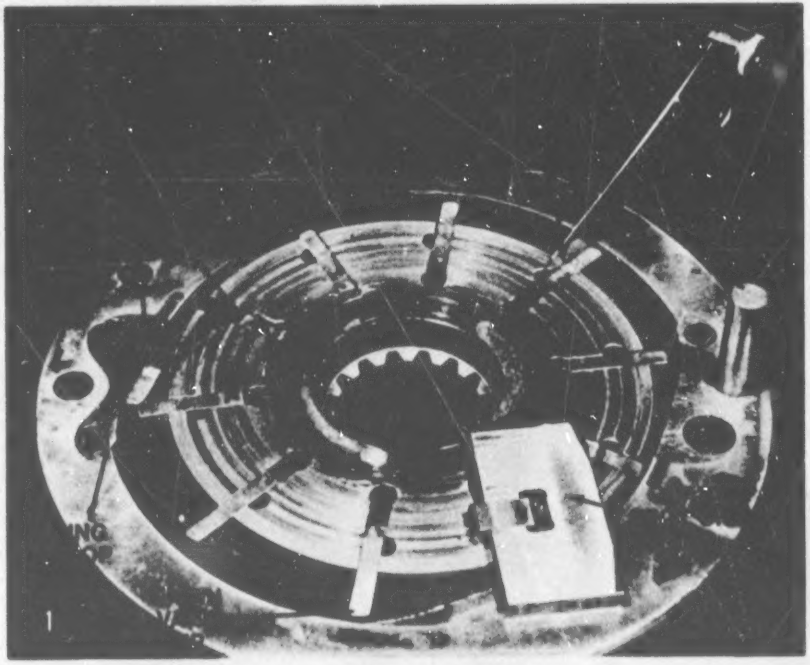
MISCELLANEOUS FAILURES — Chapter 11

INTRODUCTION

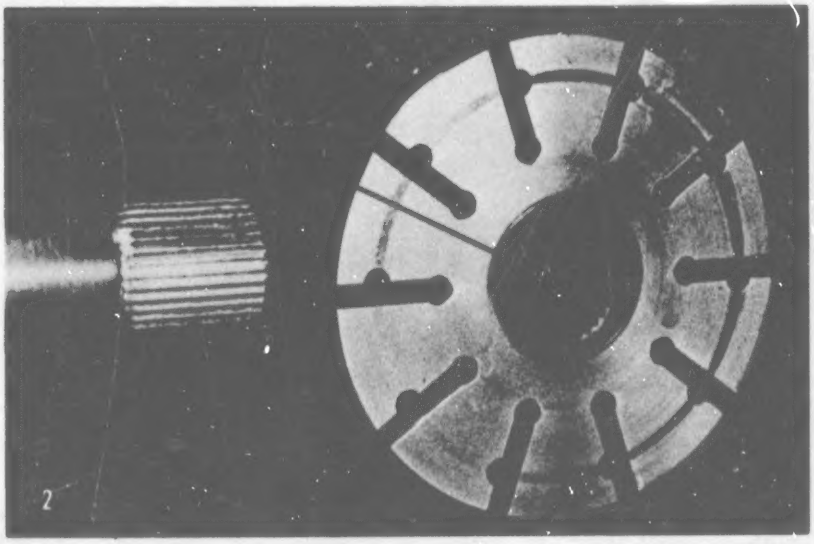
This section deals with miscellaneous failures of the following parts:

- **Pump rotors**
- **Pump impellers**
- **Disk blades**
- **Spark plugs**

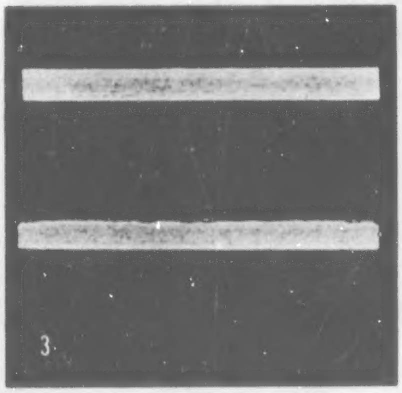


PUMP ROTORS

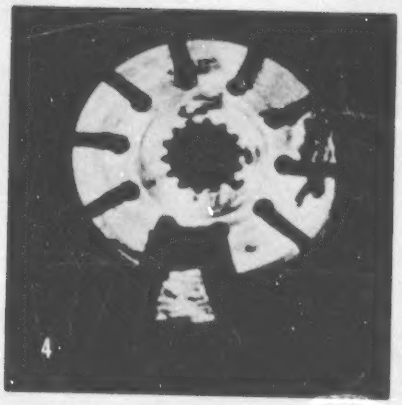
One of the most common causes of rotor damage is abrasive wear. Fig. 1 shows various forms of damage to a hydraulic pump rotor. Vanes are gray and rotor slot wear is more than 0.002 inch (0.05 mm). Vane tips are worn and the rotor seized. The cam ring has two abrupt chop marks 180° apart. One vane broke from the impact of striking the steps in the cam ring.



A worn cam ring caused rotor and shaft spline wear (arrows) in Fig. 2. Vanes bouncing on a cam-ring surface badly worn from abrasives causes spline wear.



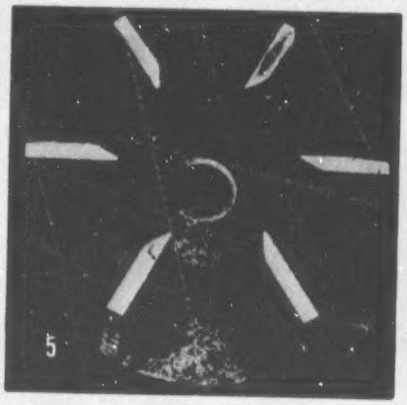
Contaminants in the oil wore the vane tips in Fig. 3. In normal operation the vane is held against the ring and a film of oil lubricates the vane tips and cam ring.



4

Contaminated fluid can damage a pump in many ways. Solid particles of dirt and sand in the fluid act as an abrasive on the closely fitted parts. This causes abnormal wear on the parts.

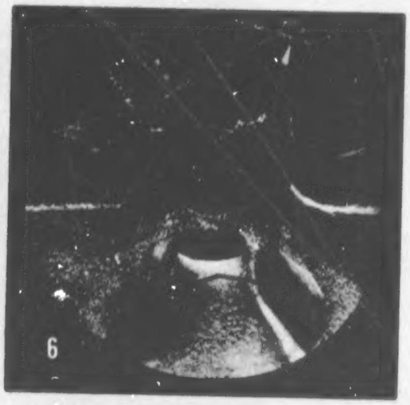
Sludge is formed by the chemical reaction of fluid to excessive temperature change or condensation. It builds up on the pump's internal parts and eventually plugs the pump (Fig. 4). If the pump is plugged on the inlet side, it will be starved for fluid and the heat and friction will cause the pump parts to seize.



5

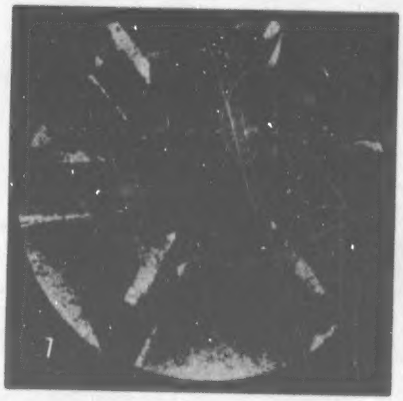
PUMP IMPELLERS

Abrasive wear occurs when hard particles slide or roll under pressure across a surface, or when a hard surface rubs across another surface. Surface projections in the harder object scratch or gouge the softer material.



6

A new impeller (Fig. 5) can be compared to the worn impeller in Fig. 6 which comes from an engine with sand in the cooling system. Erosive action of the abrasive particles moving at high speed progressively rounded the vane corners, gradually changing its shape.

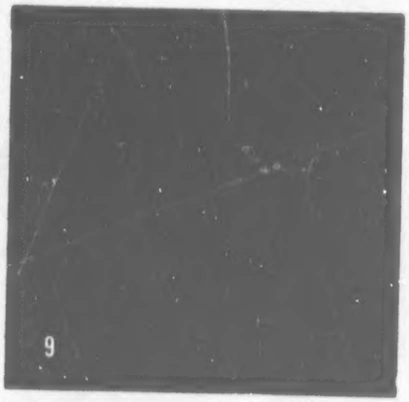


7

Another form of impeller damage is cavitation corrosion. Cavitation corrosion or erosion is caused by a relative motion between a metal surface and a liquid. Small cavities of air in the liquid form and then collapse. This produces high impact forces on the metal, resulting in cavitation pits.

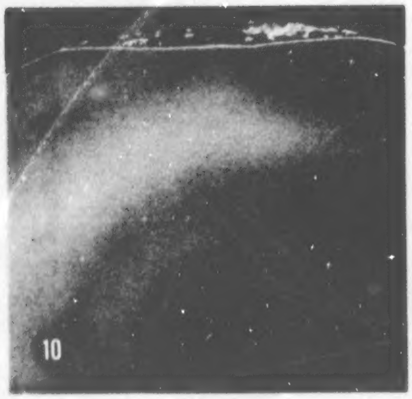
8

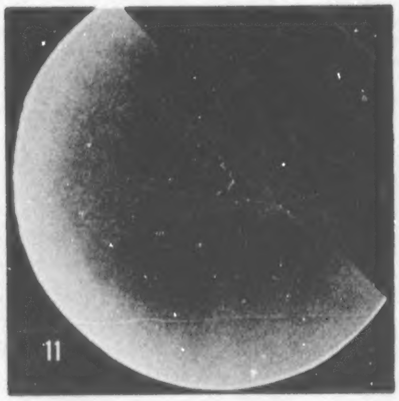
The water pump impeller in Fig. 7 was damaged by cavitation. Another case of cavitation attack on pump impeller is shown in Fig. 8.

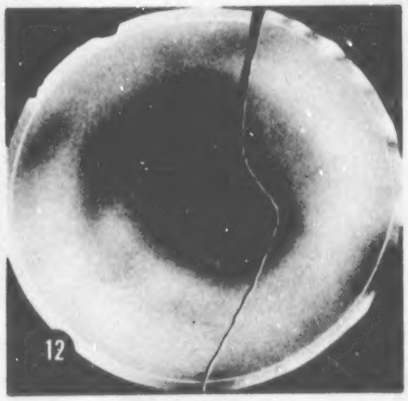


9

Fig. 9 illustrates corrosion-erosion on a bronze pump impeller bushing. Water was flowing too fast.





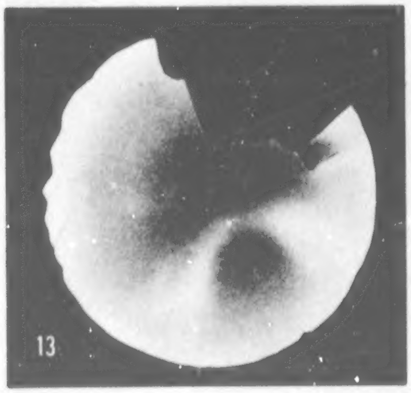


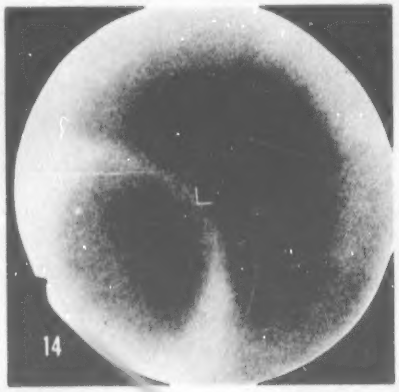
DISK BLADES

The six illustrations in this section represent the disk-blade failures most often encountered.

Disk-blade failures in Figs. 10 and 11 resulted from a defective material.

Figs. 12 and 13 illustrate non-directional break, resulting from rock or stump conditions.





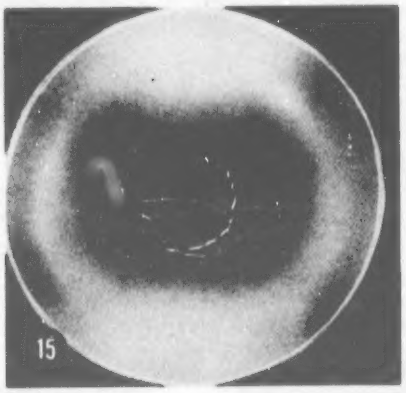
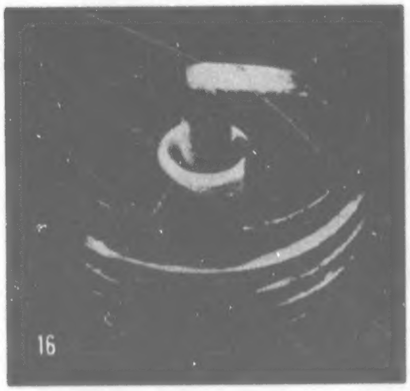
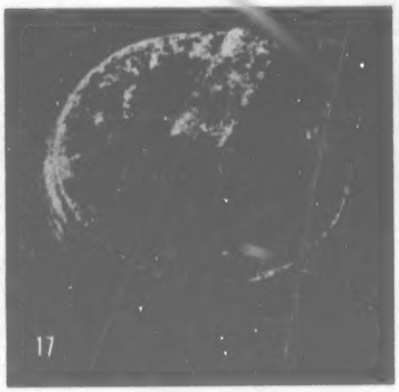
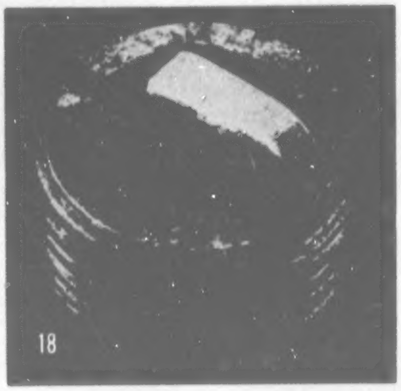


Fig. 14 illustrates chipping caused by rock or stump conditions.

In Fig. 15 the center was broken out; caused by rock or stump conditions.







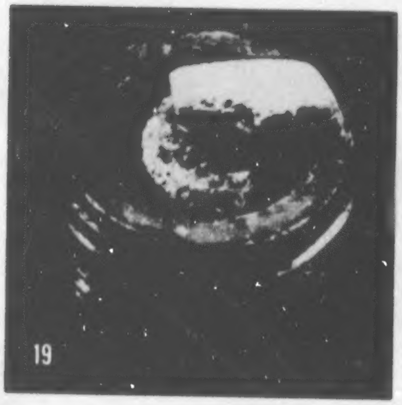
SPARK PLUGS

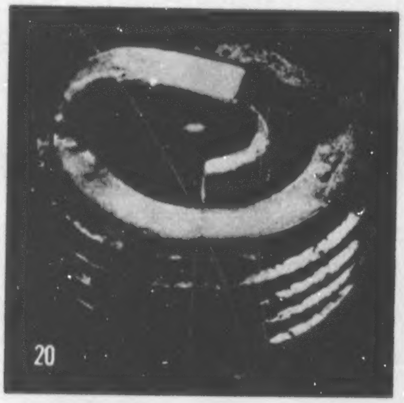
A spark plug with brown to grayish-tan deposits (Fig. 16) and slight electrode wear is normal and indicates good engine adjustments.

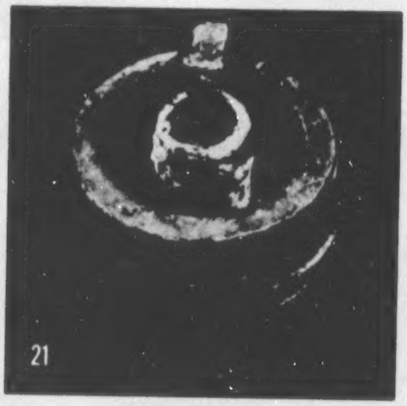
Wet oil deposits (Fig. 17) with a minor degree of electrode wear may be caused by oil pumping past worn rings or excessive valve stem guide clearance.

"Break-in" of a new or recently overhauled engine before rings are fully seated may also result in this condition.

Dry, fluffy and black carbon deposits (Fig. 18) result from over-rich carburetor adjustments. A clogged air cleaner can restrict air flow to the carburetor causing rich mixtures. Poor ignition output (faulty breaker points, weak coil or condenser) can reduce voltage and cause misfiring. A fouled spark plug is the result, not the cause of this problem.







Red, brown, yellow, and white colored coatings (Fig. 19) which accumulate on the insulator are by-products of combustion and come from the fuel and lubricating oil, both of which today, generally contain additives.

Heat shock (Fig. 20) is a common cause of broken and cracked insulator tips. Incorrect ignition timing and a poor grade fuel are usually responsible for heat shock failures. Rapid increase in tip temperature under severe operating conditions causes the heat shock and fracture results.

Another common cause of chipped or broken insulator tips is carelessness in regapping by either bending the center wire to adjust the gap, or allowing the gapping tool to exert pressure against the tip of the center electrode or insulator when bending the side electrode to adjust the gap. Install a new spark plug.

Pre-ignition (Fig. 21) causing burned or blistered insulator tip and badly eroded electrodes indicates excessive overheating. Clogged shrouding, dirty engine fins and sticky valves can also result in pre-ignition. Lean fuel-air mixtures are an additional cause.

GLOSSARY

A

ABRASIVE WEAR — Surface damage caused by sliding contact with particles of hard foreign materials.

ADHESIVE WEAR — Surface damage commonly caused by metal-to-metal contact. Microscopic surface irregularities weld together, then tear apart resulting in scuffing or scoring of one or both of the surfaces in contact.

ANTI-FRICTION BEARINGS — Friction-reducing devices that use rolling contact components between mating surfaces such as balls or rollers.

B

BACKLASH (Gears) — The clearance, or "play" between two gears in mesh.

BANDED V-BELTS — Multiple V-belts permanently vulcanized to a tie band.

BEARINGS — See anti-friction bearings and journal bearings.

BEARING PLATES — A part in a hydrostatic transmission or hydraulic pump.

BORE — The internal surface of a cylindrical opening.

BRINELLING — The effect of one piece of metal being pressed into another, causing depressions to form on one or both contacting surfaces.

C

CAMSHAFT — The shaft containing lobes or cams to operate the engine valves.

CARBON DEPOSITS — Hard built-up deposits on surfaces formed on engine parts exposed to gaseous products of combustion.

CARBURIZATION — The addition of carbon to the surface of steel parts, by heat treatment, to provide high hardness for improved wear resistance and durability. A form of case-hardening often applied to highly loaded gears.

CASE CRUSHING — Crushing of the outer surface (case) of a gear that has been case-hardened by heat treatment.

CAVITATION DAMAGE — Pitting of a metal surface exposed to a moving liquid by the collapse of entrained vapor bubbles. Corrosion is often a factor.

CHAINS — A flexible series of metal links, or rings, fitted into one another.

CHEMICAL CORROSION — Surface damage caused by contact with a chemically active liquid or gas — such as rusting of steel in contact with moist air or water.

COLD FLOW — Metal movement, under high pressure, at room temperature.

COMBUSTION KNOCK — A noise that occurs when fuel in a cylinder is ignited too early, too rapidly, or unevenly.

CONTAMINATION — Foreign material that could damage a part.

CORROSION — See chemical corrosion.

CRANKSHAFT — The main drive shaft of an engine which converts reciprocating motion to rotary motion by means of cranks.

CRUSH — A condition in journal bearings. Each half of the bearing insert must extend a very small amount beyond the parting edges of the rod and rod cap. When the capscrews or rod bolts are tightened, the bearing halves are pressed into the bore for a snug fit.

CYLINDER BLOCK — The housing of an engine, a hydraulic pump or a hydraulic motor containing the cylinder bores along with other functional components.

CYLINDER BORE — The inside surface of the passage in a cylinder block in which a piston moves.

CYLINDER BORE BUSHING — A sleeve or tube between the piston and cylinder block in a hydrostatic transmission.

CYLINDER HEAD — That part of an engine bolted to the cylinder block, forming the closed end of the combustion chamber. It contains the valves and the passages for fuel, air, exhaust gases and cooling water.

CYLINDER LINER — A replaceable sleeve or tube inserted in the cylinder block to provide a renewable cylinder bore in engines.

D

DETONATION — Uncontrolled combustion accompanied by a loss of power and waste of energy.

DRIVE BELT — A belt used to transmit power between a driving and a driven pulley.

E

ELECTRICAL PITS — Removal of a small portion of surfaces in contact by an electrical current.

EROSION — The wearing away of a surface by the impingement of abrasive particles suspended in a gas or liquid.

F

FATIGUE — Failure of a part initiated by cracking resulting from repeated subjection to stresses too low to cause failure in a single application.

FIT RUST — Rusting that results when the outer race of an anti-friction bearing fits too loose in its housing. A particular form of fretting (See Fretting).

FLAKING — The separation of thin layers from the surface of a metal part.

FOREIGN MATERIAL — Any substance that is in a place where it is not supposed to be. An example is dirt in lubricating oil.

FRETTING — A type of wear resulting from slight reciprocating movement between metal parts that are in close contact. Generally accompanied by corrosion or rusting.

G

GALLING — Surface damage on mating, moving metal parts due to friction. A severe form of adhesive wear. (See Adhesive Wear).

GEAR — A cylinder or cone-shaped part having teeth on one surface which mate with and engage the teeth of another part which is not on the same axis.

GLOW PLUG — A device designed to improve starting conditions in some diesel engines. A heating element in the combustion chamber or intake manifold.

GOUGING — Severe grooving of a surface by sliding or impact of large, hard particles.

GROOVE — A long, narrow channel in a surface.

H

HYDROSTATIC TRANSMISSION — A hydraulic transmission which uses fluid under pressure to transmit engine power to the drive wheels of the machine.

I

IMPACT FAILURE — The failure of a part that results from a single blow or suddenly applied force sufficient to cause an immediate fracture.

J

JOURNAL BEARING — Bearings that provide a sliding contact between mating surfaces; bushings.

K

KNOCKING — A noise that occurs when fuel in a cylinder is ignited too early, too rapidly, or unevenly.

L

LINK (Track and Undercarriage) — A section of a track. A series of links, connected in chain-like manner by bushings and pins, attached to the respective track shoes make up the track.

LUBRICATION — Use of a substance (grease, oil, etc.) to reduce friction between parts or objects that move against each other.

LUGGING — Occurs when an engine operating at a specified rpm is given a load it cannot support at the same, or a higher, rpm.

O

OIL RING — The piston ring nearest the bottom of the piston that controls lubrication between the piston and cylinder liner.

OVERFUELING — Allowing more fuel to enter the engine combustion chamber (thus greater stress on parts) than the engine was designed to handle.

OVERHEATING — Allowing the temperature of an object to heat to a higher temperature than it was designed to handle.

OVERLOADING — Allowing the weight that an object carries or pulls to become greater than the object was designed to handle.

OVERSPEEDING — Allowing the rpm of an engine to accelerate to a higher level than the engine was designed to handle.

P

PINION — The smaller of two meshing gears.

PISTON — A cylindrical part closed at one end which is connected to the crankshaft by the connecting rod. The force of the expanding gases in the cylinder is exerted against the closed end of the piston causing the connecting rod to move the crankshaft.

PISTON RING — An expanding ring placed in the grooves of the piston to seal off the passage of fluid or gas past the piston.

PITTING (Gears or Bearings) — A type of surface damage occurring under repeated loading of two parts in rolling or sliding contact. A form of surface fatigue.

PLANET GEAR — Gears in a planetary gear set which connect the sun gear to the ring gear.

PREIGNITION — Ignition occurring earlier than intended (gasoline engine). For example, the fuel-air mixture being ignited in a cylinder by an extremely hot particle in the combustion chamber before the electrical spark occurs.

PUMP IMPELLER — The rotating member in a pump that provides continuous power to move fluids.

PUMP ROTOR — Similar to pump impeller.

PUSH ROD — A tubular or solid rod for transmitting motion between the valve lifters and rocker arms in an internal combustion engine. The push rod is actuated by the cams on the camshaft to open and close valves.

R

RIDGING — Deformation of the working surface of gear teeth caused by high stress between two gears in mesh.

RING GEAR — A ring shaped part having teeth on either the outside or inside diameter. Examples of this are the starter ring gear, the gear which surrounds the sun and planet gears in a planetary system or the spiral bevel gear in a differential.

RIPPLING — A periodic wave-like formation on gear teeth caused by high stress between two gears in mesh.

ROCKER ARM — In an internal combustion engine, a lever that is pivoted near its center operated by a push rod at one end to depress the valve stem at the other end.

ROLLERS (Track and Undercarriage) — Rolling members of a track that prevents the track from sagging on the top by supporting the weight of the upper portion of the track. Rollers mounted on the bottom of the frame support much of the machine's weight.

ROTATING ASSEMBLY (Turbocharger) — The parts in a turbocharger that turn or rotate (wheels and shaft).

RUPTURE (Belt) — The surface appearance of a broken belt.

S

SCORING — Grooving of the surface of one or both parts in relative motion to each other by particles of a hard foreign material which may be free or embedded in one of the surfaces.

SCUFFING — A form of surface damage caused by intermittent lack of lubrication (see Adhesive Wear).

SEIZURE — The sudden stopping of motion between two parts because of excessive friction and heat between parts. Heat causes the parts to expand reducing clearance between the two parts to zero.

SHAFT — A long, slender, usually cylindrical part.

SHOCK LOADING — Placing an extremely heavy load on a part for a short period of time.

SLUDGE — A precipitate from oils, such as products from crankcase oils in engines.

SMEARING — The displacement of surface metal from one area of the surface to another; usually caused by another part rubbing on the surface with insufficient clearance and lubrication between parts.

SPALLING — Breaking off of small particles from the surface of a part. Repeated stress from heavy contact between two metal surfaces (such as gears in mesh) causes spalling. An advanced stage of pitting.

SPARK PLUG — A device that screws into the cylinder of an internal combustion engine (gasoline) having a pair of electrodes between which an electrical discharge is passed to ignite the fuel air mixture.

SPINDLE — A short, slender, tapered shaft.

SPROCKET — A wheel having teeth which engage the links of a chain for the purpose of transmitting power.

STATIC FAILURE — Failure of a part because the load was too high (overloading).

STEERING KNUCKLE — The hinged or articulated assembly for transmitting force from the steering spindle to the front axle for controlling direction of travel.

STRESS — The load per unit area.

SWASHPLATE — A plate in a hydrostatic transmission that controls the position and movement of the pistons and thus determines the speed and direction in which a machine moves.

T

TAPPET — The adjusting device for varying the clearance between the valve stem and the cam. May be built into the valve lifter in an engine or may be installed in the rocker arm on an overhead valve engine.

TORQUE — The effort of twisting or turning.

TORSIONAL FATIGUE — The cracking or failure of a part due to continuous or repeated twisting on the part at a force too great for the part to withstand.

TRACK (Crawler) — An assembly consisting of ground engaging shoes attached to track links, driven by a sprocket, to propel a crawler vehicle.

TRANSMISSION — An assembly of gears or other elements used to obtain variations in speed or direction between the input and output shafts.

TURBOCHARGER — An exhaust-driven turbine which drives a centrifugal compressor wheel.

U

UNIVERSAL JOINT — A linkage that transmits rotation from one shaft to another not collinear with it.

V

VALVE — Any movable device for controlling the movemove of a liquid or gas by opening or closing a passage. In an engine, the device for opening and closing the cylinder intake and exhaust ports.

VALVE GEAR TRAIN — The engine valves and valve operating mechanism that controls fuel and air flow to and from the combustion chamber.

VALVE SEAT — The matched surface upon which the valve face rests.

VALVE SPRING — A spring attached to a valve to return it to its seat after it has released from the lifting or opening means.

VALVE STEM GUIDE — A bushing or hole in which the valve stem slides.

V-BELT — Belts that transmit power between drive and driven pulleys or sheaves. The area of the belt that fits in the sheave groove is shaped like a "V" so it can be wedged against the sides of the sheave groove to provide enough friction to transmit power.

VIBRATION — A quivering or trembling motion.

INDEX

A

- Abrasive wear (also see dirt)
  - Gears 5-1, 5-2
  - Pump impellers 11-2
  - Pump rotor 11-1
- Adhesive wear
  - Gears 5-1, 5-2
  - Piston 1-2
  - Valve tappet 3-2
- Anti-friction bearing
  - Contamination 8-1
  - Careless handling 8-4
  - Corrosion 8-2
  - Defective bearing material 8-8
  - Electric current 8-7
  - Electric leak 8-8
  - Electric pits 8-8
  - Fatigue 8-5, 8-7
  - Installation 8-4, 8-5
    - Split race 8-4
    - Fit rust 8-4
    - Creep wear 8-4
  - Lubrication 8-2, 8-3
  - Misalignment 8-6
  - Overloading 8-7
  - Overspeeding 8-7
  - Pitting 8-1
  - Severe service 8-6
  - Vibration 8-7
- Axles
  - Fatigue 6-2
  - Impact 6-2
  - Improper use 6-3

B

- Backlash 5-10
- Ball guides
  - Scoring 7-3
  - Wear 7-3
- Banded V-belts
  - Cracking 9-6
  - Fraying 9-6
  - Riding outside sheave groove 9-5
  - Separating 9-6
  - Sheave groove 9-5
  - Tie band 9-6
- Bearings
  - Anti-friction 8-1
  - Journal 2-1
- Bearing bore, journal 2-2, 2-3
- Bearing plates
  - Bi-metal 7-5
  - Cavitation 7-5
  - Discoloration 7-4, 7-5
  - Erosion 7-4
  - Grooved 7-4
  - Smearing 7-4
- Belts
  - Banded V-belts 9-5, 9-6
  - Flat 9-7
  - Snowmobile 9-7
  - V-belts 9-1 thru 9-5
- Breakage (also see cracking)
  - Piston 1-3, 1-4
  - Piston ring 1-8
  - Valve 3-3
- Brinelling, universal joints 6-6
- Burn
  - Flat belts 9-7
  - V-belts 9-2

C

- Cam ring, pump rotor 11-1
- Camshaft 3-5
- Carbon deposits
  - Piston ring breakage 1-8
  - Piston ring sticking 1-8
  - Preignition, piston 1-2
  - Spark plugs 11-4
  - Valve 3-1
  - Valve guide 3-3
- Carburized gear 5-5
- Case crushing, gears 5-1, 5-3, 5-5
- Cavitation (also see erosion)
  - Cylinder liner 1-11
  - Hydrostatic transmission
    - Bearing plate 7-5
    - Piston 7-2
  - Pump impellar 11-2
- Chains
  - Corrosion 9-8
  - Fracture 9-8
  - Galling 9-8
  - Wear 9-8
- Charge pump, hydrostatic trans. 7-7
- Chemical corrosion (also see corrosion), cylinder liners 1-10
- Chipping, piston ring 1-6, 1-8
- Cold flow gears 5-1, 5-7, 5-8
- Combustion
  - Piston 1-1, 1-3, 1-5
  - Piston ring 1-8
  - Valve erosion 3-2
- Combustion knock
  - Piston 1-1, 1-2
  - Piston ring sticking 1-9
- Contamination
  - Anti-friction bearings 8-1
  - Hydrostatic transmission, valve plate 7-6
  - Pump rotor 11-1
- Cooling System
  - Tappet clearance 3-2
  - Valve seat distortion 3-1
- Corrosion (also see chemical corrosion)
  - Anti-friction bearings 8-2
  - Chains 9-8
  - Gears 5-1, 5-2
  - Journal bearings 2-4
  - Piston 1-3
  - Piston ring 1-7
- Cracking (also see breakage)
  - Banded V-belts 9-6
  - Cylinder liners 1-10
  - Gears 5-6
  - Piston 1-3, 1-4
  - Steering knuckle 6-5
  - Valve 3-2
  - V-belts 9-1
- Crankshaft
  - Bearing journal 6-4
  - Fatigue 6-2
  - Piston damage 1-3
- Creep-wear, anti-friction bearing 8-4
- Crush, journal bearings 2-3
- Cylinder bore bushings, hydrostatic transmission 7-3
- Cylinder block
  - Fracture 7-4
  - Pulled bushing 7-3
- Cylinder liners
  - Cavitation 1-11
  - Chemical corrosion 1-10
  - Cracking 1-10
  - Wear 1-11

D

- Detonation, piston 1-1
- Diesel engine
  - Piston 1-3, 1-5

- Crankshaft 6-4
- Valve 3-1, 3-2

Differential spider arm 5-11

Dirt (also see abrasive wear and contamination)
- Crankshaft 6-4
- Journal bearing 2-1
- Valve stem 3-2

Discoloration
- Slipper retainer 7-3
- Bearing plate 7-4, 7-5

Disk blade 11-3

Drive belt, snowmobile 9-7

E

Electric current
- Anti-friction bearing 8-7
- Journal bearing 2-4

Electric leak, anti-friction bearing 8-8

Electric pits, anti-friction bearing 8-8

Erosion (also see cavitation)
- Bearing plates 7-4
- Piston 1-5, 1-6
- Pump impellers 11-2
- Turbocharger wheel 4-1

F

Fatigue
- Anit-friction bearings 8-5, 8-7
- Axles 6-2
- Bending fatigue 6-1
- Crankshaft 6-1
- Gears 5-1, 5-5, 5-6
- Ring gear 5-5
- Torsional 6-2
- Universal joints 6-6, 6-7
- Valve tappet 3-4

Fit-rust, anti-friction bearings 8-4

Flaking, valve tappet 3-4

Flat belts
- Burn 9-7
- Tear 9-7

Foreign material (also see abrasive wear, dirt, and contamination)
- Anit-friction bearings 8-1
- Gear 5-1
- Turbocharger 4-1, 4-5
- V-belts 9-2

Fretting
- Anti-friction bearings 8-4
- Shaft 6-3, 6-4

Fuel
- Combustion 1-1
- Knocking 1-1
- Piston 1-1
- Valve erosion 3-2

Fuel injection nozzle, piston erosion 1-5

G

Galling
- Chains 9-8
- Piston slipper 7-2
- Swashplate 7-1
- Thrust plate 7-1
- Transmission shaft 6-4
- Universal joints 6-6

Gasoline engine
- Piston 1-1, 1-3
- Piston ring 1-9
- Preignition 1-9

Gears
- Carburized gear 5-5
- Cold flow 5-1
- Cracking 5-6
- Differential pinion 5-11
- Differential side gear 5-11, 5-12
- Drive pinion 5-4, 5-11
- Fatigue 5-1, 5-5, 5-6
- General failures 5-2
- Impact 5-1, 5-7
- Oil pump idler gear 5-5
- Planet gear 5-6
- Ridging 5-1
- Ring gear 5-5, 5-11
- Ring gear teeth 5-10
- Rippling 5-1
- Specific failures 5-10
- Terminology 5-1
- Transmission
  - Countershaft 5-13
  - Helical 5-12
  - Mainshaft 5-12
  - Mainshaft 2nd gear 5-13
  - Overdrive 5-13
- Wear 5-1

Glow plug, piston breakage 1-3

Gouge, V-belt 9-2

Grooving
- Bearing plate 7-4
- Shaft seal 7-6
- Valve plate 7-6

H

Hydrostatic systems
- Light duty 7-8
- Heavy duty 7-1, 7-8

Hydrostatic transmissions
- Ball guides 7-3
- Bearing plates 7-4, 7-5
- Charge pump assembly 7-7
- Cylinder block 7-3
- Displacement control valve 7-7
- Piston/slipper assembly 7-1
- Servo sleeve and piston 7-7
- Shafts 7-6
- Shaft seal 7-6
- Slipper retainer 7-3
- Swashplates 7-1
- Thrust plates 7-1
- Valve plate 7-6

I

Impact failures
- Axles 6-2
- Gears 5-1, 5-7

Installation, anti-friction bearings 8-4

J

Journal bearings
- Bearing bore 2-2
- Corrosion 2-4
- Crush 2-3
- Dirt 2-1
- Electric current 2-4
- Improper assembly 2-2
- Lack of lubrication 2-2
- Misalignment 2-3
- Overloading 2-3
- Tapered journals 2-2
- Turbocharger 4-3, 4-4

K

Knocking
- Combustion 1-1
- Fuel 1-1
- Piston, gasoline engine 1-1

L

- Link, track 10-1
- Lubrication
  - Anti-friction bearings 8-2, 8-3
  - Ball guide 7-3
  - Cylinder block 7-3
  - Crank 6-4
  - Differential spider arm 5-11
  - Drive pinion 5-11
  - Gears 5-2, 5-9
  - Journal bearing 4-3, 2-2, 2-4
  - Piston slipper 7-2
  - Ring gear 5-11
  - Rocker arm 3-3
  - Transmission shaft 6-4
  - Turbocharger 4-2
    - Shaft 4-2
    - Thurst bearings 4-5
  - Universal joints 6-6
  - Valve 3-2
- Lugging
  - Combustion knock 1-1
  - Scoring (piston) 1-2
  - Scuffing (piston) 1-2

M

- Misalignment
  - Anti-friction bearings 8-6
  - Gears 5-3
  - Hydrostatic transmission shaft 7-4, 7-8
  - Journal bearings 2-3
  - Push rod 3-4
  - Track, sprocket 10-1
  - V-belts 9-4

O

- Oil pump idler gear 5-5
- Oil-ring 1-7
- Overfueling
  - Combustion knock 1-1
  - Piston ring
    - Scoring 1-8
    - Scuffing 1-8
    - Sticking 1-19
- Overheating
  - Crank 6-4
  - Drive pinion 5-11
  - Hydrostatic transmission, piston 7-2
  - Journal bearing 2-3
  - Ring gear 5-11
  - Piston 1-1, 1-2
  - Shaft 4-3
  - Thrust bearing 4-5
  - Transmission shaft 6-4
  - Valve 3-2, 3-3
- Overloading
  - Anti-friction bearing 6-4, 8-7
  - Chains 9-8
  - Differential spider arm 5-11
  - Drive pinions 5-11
  - Gears 5-1 thru 5-5, 5-7 thru 5-9
  - Journal bearings 2-3
  - Ring gear teeth 5-10
  - Shaft 6-1, 6-3
  - V-belt 9-2
- Overspeeding
  - Anti-friction bearings 8-7
  - Hydrostatic transmission
    - Cylinder block 7-3
    - Piston slipper 7-2
  - Piston 1-4
  - Valve tappet 3-4

P

- Pinions
  - Differential 5-11
  - Drive 5-4, 5-8 thru 5-11
  - Side 5-11
- Piston
  - Diesel engines
    - Breakage 1-3, 1-4
    - Cracking 1-3
    - Erosion 1-5
    - Scuffing 1-5
    - Seizure 1-4, 1-5
    - Wear 1-4
  - Gasoline engines
    - Corrosive wear 1-3
    - Detonation 1-1
    - Knocking 1-1
    - Physical damage 1-3
    - Preignition 1-2
    - Scoring 1-2
    - Scuffing 1-2
- Piston filler, separation 7-2
- Piston pin lock 1-3
- Piston ring
  - Breakage 1-8
  - Chipping 1-8
  - Scoring 1-8
  - Scuffing 1-8
  - Sticking 1-9
  - Wear 1-6, 1-7
- Piston slipper
  - Galling 7-2
  - Overspeeding 7-2
  - Scoring 7-1
  - Smearing 7-2
- Pitting
  - Anti-friction bearings 8-1
  - Gears 5-1, 5-3, 5-4, 5-8
  - Valve tappet 3-4
- Planet gear 5-6
- Preignition
  - Piston
    - Carbon deposits 1-2
    - Overheating 1-2
    - Scoring 1-2
    - Scuffing 1-2
    - Spark plugs 1-2
    - Valves 1-2
  - Piston ring 1-9
- Pulled bushing (Hydrostatic Transmission) 7-3
- Pump impeller
  - Abrasive wear 11-2
  - Cavitation 11-2
  - Erosion 11-2
- Pump rotors
  - Abrasive wear 11-1
  - Cam ring 11-1
  - Contamination 11-1
  - Sludge 11-2
- Pump shaft
  - Overloading 6-4
- Push rod
  - Cup 3-4
  - Misalignment 3-4
  - Wear 3-4

R

- Rear axle differential side gears 5-12
- Ridging, gears 5-1, 5-7
- Ring gear 5-5, 5-10, 5-11
- Rippling, gears 5-1, 5-7, 5-8
- Rocker arm
  - Bolts 3-4
  - Scuffing 3-4
  - Spalled 3-4
  - Wear 3-3

Rollers, tracks 10-1
Rotating assembly, turbocharger 4-4
Rotors, pump 11-1
Rupture, V-belts 9-1

S

Scoring
    Gears 5-2
    Hydrostatic transmission
        Ball guide 7-3
        Piston slipper 7-1
        Servo sleeve 7-7
        Shaft seal 7-6
        Swashplate 7-1
        Thrust plate 7-1
    Piston 1-2
    Piston ring 1-6, 1-8
    Shafts 6-3
Scuffing
    Piston 1-2, 1-5
    Piston ring 1-6, 1-8
    Ring gear 5-10
    Rocker arm 3-4
    Valve stem 3-2
    Valve tappet 3-4
Seizure, piston 1-4, 7-3
Servo sheave, hydrostatic transmission 7-7
Shaft
    Bending fatigue 6-1
    Frettage 6-3
    Hydrostatic 7-8
    Oil starvation 4-2
    Pump 6-4
    Scoring 6-3
    Severe service 6-3
    Static failure 6-1
    Torsional fatigue 6-2
    Transmission 6-4
Shaft seal
    Fructure 7-6
    Grooving 7-6
    Scoring 7-6
Shock loading
    Gears 5-10
    Universal joints 6-7
    V-belts 9-2, 9-3
Slipper retainer
    Discoloration 7-3
    Low pressure 7-3
    Scoring 7-3
Smearing
    Hydrostatic transmission
        Bearing plate 7-4, 7-5
        Piston slipper 7-2
        Swashplate 7-1
        Thrust plate 7-1
        Valve plate 7-6
Sludge, pump rotor 11-2
Snowmobile
    Drive belt 9-7
    Tracks 10-2, 10-3
    V-belts 9-7
Spalling
    Gears 5-1, 5-3, 5-4, 5-8
    Valve tappet 304
Spark plug
    Carbon deposits 11-4
    Electrode wear 11-4
    Gapping 11-4
    Heat shock 11-4
    Oil deposits 11-4
    Preignition 1-2, 11-4
Spindle
    Steering knuckle 6-5
    Wear 6-5
Split race, anti-friction bearing 8-4
Sprocket, tracks 10-1
Static failure, shaft 5-1
Steering knuckle, crack 6-5
Stress
    Differential side gear 5-11
    Gear 5-8
Swashplate
    Galling 7-1
    Scoring 7-1
    Smearing 7-1

T

Tappet
    Clearance 3-2
    Surface fatigue 3-4
    Wear 3-4
Tear
    Flat belt 9-7
    V-belt 9-2
Thrust bearing, turbocharger 4-5
Timing
    Combustion knock 1-1
    Erosion 1-5, 1-6
    Scuffing 1-5
Tires
    Cuts 10-5
    Fabric breaks 10-3, 10-4
    Rubber checks 10-4
    Tread wiping 10-5
    Wear 10-4
Thrust plates
    Galling 7-1
    Scoring 7-1
    Smearing 7-1
Torque, universal joints 6-7
Torsional fatigue, shaft 6-2
Tracks
    Links 10-1
    Rollers 10-1
    Snowmobile 10-2
    Sprocket 10-1
Transmission
    Countershaft 5-13
    Helical gear 5-12
    Hydrostatic 7-1 thru 7-8
    Mainshaft 5-12
    Overdrive gear 5-13
    Second speed gear 5-13
    Shaft 6-3, 6-4
Turbocharger
    Blade tip 4-1
    Housing 4-5
    Impeller 4-1
    Journal bearing 4-3
    Shaft 4-2
    Thrust bearing 4-5
    Wheels 4-1

U

Universal joints
    Brinelling 6-6
    Fatigue 6-6
    Galling 6-6
    Journal 6-7
    Lubrication 6-6

V

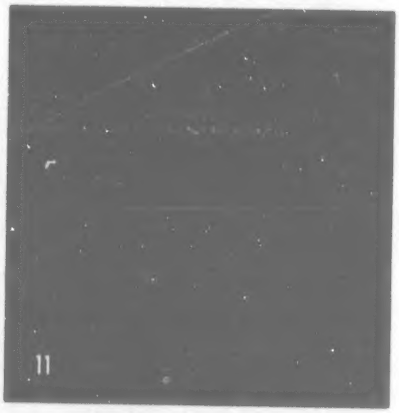
Valve
    Breaks 3-3
    Camshaft 3-5
    Cracking 3-2

  - Erosion 3-2
  - Overheating 3-2
  - Piston damage 1-3
  - Piston preignition 1-2
  - Push rod 3-4
  - Rocker arm 3-3
  - Scuffing 3-2
  - Tappet 3-2, 3-4
  - Valve deposits 3-1
  - Valve seat distortion 3-1
  - Valve guides 3-3
  - Valve spring 3-1, 3-5
  - Wear 3-3
- Valve gear train 3-1, 3-5
- Valve guides 3-3
- Valve plate
  - Contamination 7-6
  - Grooving 7-6
  - Smearing 7-6
- Valve spring 3-1, 3-5
- Valve seat
  - Distortion 3-1, 3-2
  - Wear 3-3
- V-Belts
  - Banded 9-5, 9-6
  - Burn 9-2
  - Cracking 9-1
  - Cuts 9-4
  - Gouges 9-2, 9-3
  - Internal cord 9-4
  - Peeling 9-5
  - Rupture 9-1
  - Snowmobile 9-7
  - Tear 9-2
  - Wear 9-3, 9-4
- Vibration
  - Anti-friction bearing 8-7
  - Chains 9-8

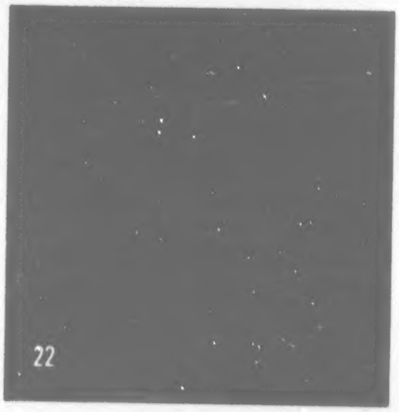
W

- Wear
  - Anti-friction bearing 8-4
  - Ball guide 7-3
  - Bearing bore 4-4
  - Chains 9-8
  - Cylinder liner 1-11
  - Gears 5-1, 5-2, 5-14
  - Journal bearing 2-1, 2-2, 2-3
  - Pinion bearing 5-10
  - Piston 1-4
  - Piston ring 1-6, 1-7
  - Push rod 3-4
  - Rocker arm 3-3
  - Spindle 6-5
  - Tire 10-4
  - Track, sprocket 10-1
  - Valve 3-3
  - Valve tappet 3-4
  - V-belts 9-3, 9-4

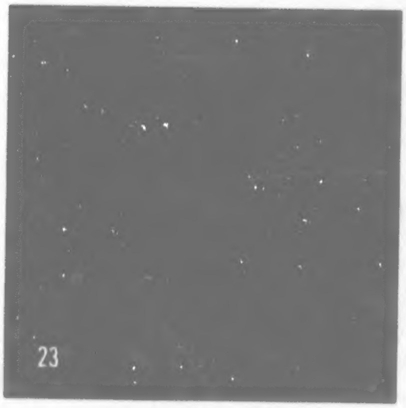
See page 7-2



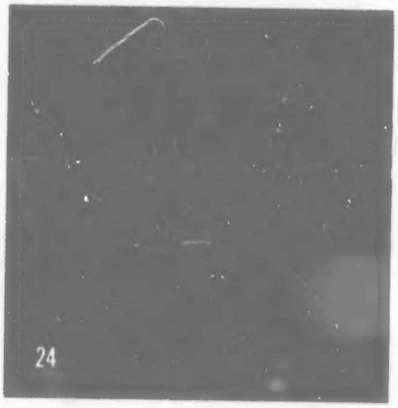
See page 7-3



See page 7-4



See page 7-5



See page 7-5